PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 13 December 1999 (13.12.99)	
International application No. PCT/HU99/00035	**Applicant's or agent's file reference** 68.002/BT
International filing date (day/month/year) 04 May 1999 (04.05.99)	**Priority date** (day/month/year) 05 May 1998 (05.05.98)
Applicant RAMANUJAM, P., S. et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

22 November 1999 (22.11.99)

[ ] in a notice effecting later election filed with the International Bureau on:

_____

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Jean-Marc Vivet
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

15

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
68.002/BT		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/HU99/00035	04/05/1999	05/05/1998
International Patent Classification (IPC) or national classification and IPC G11B7/00		
Applicant OPTILINK AB et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 9 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 7 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
22/11/1999	05.09.00
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Chaumeron, B Telephone No. +49 89 2399 2662

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/HU99/00035

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1,2,4-28	as originally filed			
3a-3b	as received on	28/07/2000	with letter of	28/07/2000

Claims, No.:

1-23	as received on	28/07/2000	with letter of	28/07/2000

Drawings, sheets:

1/7-7/7	as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

☐ restricted the claims.

☒ paid additional fees.

☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-23
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-23
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-23
	No:	Claims	

2. Citations and explanations

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item IV

Lack of unity of invention

1.) The separate groups of invention are:

i.) Claims 1,9: recording and reading information on a holographic recording medium using different write and read wavelengths, and corresponding apparatus.

ii.) Claim 5: Holographic recording medium having a polarisation sensitive polymer material and a specific thickness.

iii.) Claim 19: Method for coding information recorded on a holographic recording medium.

More precisely, it appears that the preamble of claim 1 as well as the additional feature of claim 1 in lines 7,8 is known from D1 (see D1, page 1234, left hand column, lines 6th and 7th sentences; right hand column , last paragraph; page 1235, left hand column, line 16 to right hand column, line 3).
The remaining feature (called A in the following) seems not to be known from the available prior art documents.

There is no technical relationship in the sense of Rule 13.2 PCT between this feature A and the features of the characterising portion of claim 5 or 19 .

The characterising portion of claim 5 is concerned with the nature and the thickness of the recording medium whereas the characterising portion of claim 19 is concerned with the arrangement of data sets in recording locations. No technical relationship in the sense of Rule 13.2 PCT can be seen here either.

Therefore there is non unity of invention between claims 1 or 9, 5 and 19.

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1: S. Hvilsted et al: "Side-chain liquid-crystalline polyesters for optical information storage" Optics Letters , vol. 17, no. 17, 1 September 1992, pages 1234-1236, NY;
D2: WO-A-97/02563;
D3: JP-A-7065138 and the corresponding Japanese abstract.

1.) Claim 1:
D1 considered as the closest prior art discloses a method for the recording and reading of data according to the preamble of claim 1. The use of two different wavelengths or reading and recording lead to distortion in the reconstructed image during reading in the readout channel. The invention which has identified this problem proposes to correct this distortion. This problem is not addressed in the available prior art documents.

2.) Claims 9 and 17 discloses a corresponding apparatus and system respectively. The same conclusion as above applies here.

3.) Claim 5
D2 discloses a holographic recording medium having a carrier substrate (46), a holographic layer sensitive to a recording light having a certain wavelength (see D2,

page 11, line 32 to page 12, line 12), and a reflection layer between the carrier substrate and the recording layer (see page 17, third paragraph).
The claimed recording medium is characterised by the presence of a polarisation sensitive recording medium with a very thin layer (0.2 to 2 times the wavelength of the reading and recording light).The claimed thickness is above the thickness values disclosed in the available prior art documents.

4.) Claim 19:

D3 which is considered as the closest prior art discloses a method for coding of the recorded information on a holographic recording medium according to the preamble of claim 1. In the method according to D3, data sets are recorded sequentially. The aim of the invention is to secure the recorded information. To achieve this object the data set are recorded in a random sequence of the recording locations. This is neither disclosed in nor suggested from the available prior art documents.

5.) Sub-claims meet as such the requirements of Article 33(1) PCT.

Re Item VII
Certain defects in the international application

1.) Since no single document discloses all the features of clam 9, the one part form is not appropriate.

2.) D3 which is relevant to claim 19 has not been cited in the description.

Re Item VIII
Certain observations on the international application

1. In claim 1, the passage: 'in the order of wavelength of the reading and recording light' (see claim 1, line 5) is not clear because:
i) it makes reference to an undetermined parameter (light wavelength); and
ii) it is said in the claim that the reading and recording light wavelength are different.
Therefore the definition is vague and does not clearly define the matter for which protection is sought.

2. In claim 1, the passage: 'in a recording' is not clear. Does it mean 'recording layer' or recording step' ... ?

3. In claim 1, The general term 'distortion' used in the characterising portion of the claim may be ambiguous. It would have been more appropriate to add: 'of the reconstructed image' as indicated in the description (see description page 5, line 14).

4. In claim 1, the characterising portion of the claim defines the invention by a result to be achieved. There is a doubt as to whether the skilled person would immediately recognize which technical features are needed to achieve this result (see PCT Guidelines III-4.7). It would have been appropriate in the present case to indicate which technical features are necessary to achieve the result (see in particular the following passages of the description: page 17, lines 11 to 19; page 20, line 25 to page 21, line 20; page 25, lines 21 to 26).

5. In claim 5, it is not clear what is meant by: 'a recording layer sensitive to a reading light'.

6. In claim 5, the claimed recording medium is specified by making reference to the wavelength of an external laser beam. This leads to a doubt regarding the matter for

which protection is sought. Furthermore the examiner is not aware of any technical standard defining the wavelengths used in the holographic recording technology field. Therefore the claim lacks clarity (how to determine whether a given holographic recording medium considered alone falls within the scope of claim 5 ?).

7. In claim 9, the extensive use of 'and/or' leading to a high number of alternatives renders the claim particularly unclear. There is at present a doubt whether all the alternatives are envisaged in the description and therefore whether the claim is supported by the description. For instance in the passage: 'polarising selector means for separating and/or combining the reference beam and the object beam' the alternative 'or' is not supported by the description. In the two next 'and/or' in line 22 the alternative 'or' is not supported by the description either.

8. The system claim 17 is characterised by a method step ('utilizing...'). This leads to a doubt as to the category of the claim (method or system ?).
Technical system features should have been recited in the claim to clearly define the matter for which protection is sought.
The attention of the applicant is drawn to the fact that in accordance with the PCT Guidelines (see par. III 4.6) the features of the portion of the claim after 'preferable' are only optional.

9. In claim 19, the use of and/or in line 22 leads to difficulties of interpretation of the claim because the alternative 'or' with 'subholograms' is not clear (because the term subhologram implicitely suggests the presence of holograms).
The meaning of the term 'random' as given in the description (see page 26, lines 5 to 18) which goes far beyond the normal definition of random should have been integrated in the claim. The same remark applies to 'random...locations' (see the same passage of the description).

Claims:

1. Method for the recording and reading of data on a recording medium, using a holographic recording medium with a thin holographic recording layer, preferably an optical card, and holographic write/read apparatus for the recording medium, wherein the recording of the information is in the form of data pages stored as thin Fourier holograms, characterised by

using reflected transmission and polarisation holography with different write and read wavelengths, and

during reading correcting the distortion in the readout channel caused by the difference between the write and read wavelengths.

2. Method according to claim 1, wherein the wavelength distortion is corrected by optical and/or software means.

3. Method according to claim 1 or 2, wherein the holograms are recorded as on-axis holograms.

4. Method according to any one of the claims 1 to 3, wherein the recording and reading is made with polarisation multiplexing and/or phase-code and/or rotational multiplexing.

5. Holographic recording medium, preferably an optical card, having a carrier substrate, a holographic recording layer sensitive to light, and a reflection layer between the carrier substrate and the recording layer, characterised by that the recording layer is a polarisation sensitive polymer material, and the thickness of the recording layer is 0.5-2 times the wavelength of the reading and/or recording light.

6. Holographic recording medium according to claim 5, wherein the reflection layer is a wavelength selective mirror reflecting on the read wavelength and transmitting or absorbing on the write wavelength.

7. Holographic recording medium according to claim 5 or 6, wherein the recording layer is an azobenzene SCP layer.

8. Holographic recording medium according to any one of the claims 5 to 7, wherein the recording layer is covered by a protective layer.

9. Apparatus for the writing and reading of a holographic recording medium, preferably an optical card, having a recording medium holding and/or positioning mechanism, movable or fixed read and write optics,
the write optics comprising a polarised writing light source, polarising selector means for separating and/or combining the reference beam and the object beam, object beam modulating means, polarisation wave plate, an objective lens for imaging the object beam onto a recording layer, and further the read optics comprising a polarised reading light source, and a polarising selector and/or spatial filtering means for separating and/or combining the reference beam and the image beam, a light detector and an objective lens for imaging the image beam onto a light detector,
characterised by that the wavelength of the reading light source is different from the writing light source, and
the read optics comprise wavelength distortion correcting means for correcting the distortion of the reconstructed image caused by the difference in the wavelength of the reading and writing light.

10. Apparatus according to claim 9, wherein the wavelength of the writing light source is between 400-550 nm, and the wavelength of the reading light source is between 600-700 nm.

11. Apparatus according to claim 9 or 10, wherein the wavelength distortion correcting means of the read optics comprise an aspherical plastic objective lens.

12. Apparatus according to any one of the claims 9 to 11, wherein the object beam and the reference beam in the read optics and/or the write optics have a common optical axis, and the polarising selector means comprise a polarisation selective beam splitter and/or the spatial filtering means comprise a beam stop for separating the reflected reference beam from the reflected object beam.

13. Apparatus according to any one of the claims 9 to 12, wherein polarisation encoder means are provided in the optical path of the reference beam.

14. Apparatus according to claim 13, wherein the polarisation encoder means are comprising a LCSLM.

15. Apparatus according to any one of the claims 11 to 14, wherein the read optics and the write optics have a common objective lens for imaging the reference and object beams onto a recording layer and for imaging the reflected object beams onto the read detector.

16. Apparatus according to claim 15, wherein the common objective lens is an aspheric lens for the correction of the wavelength distortion, the aspheric lens having a central region and an annular region in its aperture, where the central region of the aspheric lens is tuned to the wavelength of the writing light source for focusing the write object beam onto the recording layer, and at the same time tuned

to the wavelength of the read light source for imaging the read object beam onto the detector, and further the annular region of the lens is tuned to the wavelength of the read light source for imaging the reflected beam onto the detector.

17. Holographic data storage system with a holographic recording medium and a read/write apparatus for the holographic recording medium, particularly with the recording medium according to claim 5 and for a read/write apparatus according to claim 9,
characterised in utilising reflected transmission and polarisation holograms with different read and write wavelength, together with distortion correction means for correcting the distortion caused by the difference between the read and write wavelength.

18. The system according to claim 17, wherein the data storage capacity is multiplied by polarisation and/or phase code and/or rotational multiplexing.

19. Method for coding of the recorded information on a holographic optical recording medium, preferably an optical card, where the information is recorded in the form several discrete holograms and/or subholograms recorded in different physical and/or logical recording locations on the optical recording medium, the holograms containing data sets, where the sequence of the data sets together constitute the recorded information,
characterised by that the data sets are recorded in a random sequence of the recording locations.

20. The method according to claim 19, wherein the information is recorded in multiplexed holograms, and the logical recording locations are identified by the multiplexing address.

21. The method according to claim 20, wherein the information is recorded by polarisation holography using phase-code multiplexing, where one hologram contains several phase-coded multiplexed holograms, and the logical recording locations are identified by the phase code address.

22. The method according to any one of the claims 19 to 21, wherein the location of the first data set is stored, and the location of the following data sets are stored in the previous data sets.

23. The method according to any one of the claims 19 to 22, wherein the random sequence of the data sets are stored and encrypted and/or made inaccessible for unauthorised users.

optical card. US patent No. 4,888,260 discloses another method for the preparation of a volume phase reflection hologram. Here, the volume phase reflection hologram is formed by a second off-axis hologram in the same recording medium. This method is not suitable for forming erasable and re-recordable holograms, and the optical system is very complicated. US patent No. 5,710,645 discloses a method and system for recording a grazing incidence hologram, which is supported on a substrate having a thin edge-illuminatable geometry, like an optical card. Theoretically, this system could be used for data storage as well, but again the edge-illumination demands very special mechanical and optical properties of the card carrying the hologram.

Therefore, it is the object of the invention to provide a method and system for data storage based on reflection holography, where the holograms may be recorded and erased several times, preferably in an unlimited number of cycles, and where the holograms need to be accessed from one side only, both during writing and readout. Also, the holograms should be stored on an optical recording medium, preferably an optical card or disk that is easy to manufacture, and which tolerates normal daily wear, i. e. which is subjected to the same or similar treatment as a traditional plastic credit card or a floppy disk. It is a further object of the invention to provide a method and system for data storage where the read-write apparatus contains a relatively small, simple and cheap optical system. It is a further object to provide an optical recording method that ensures high data density and high data transfer rate, and at the same time allow efficient encoding or encryption of the data, and thereby provides enhanced security.

Summary of the Invention

According to the invention, this goal is achieved by a method, which uses a holographic write/read apparatus, and a recording medium, preferably an optical card, with a thin holographic recording layer. The holographic recording medium

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:
BOKOR, Tamas
S.B.G.&K. PATENT AND LAW OFFICES
Andrassy ut 113
H-1062 BUDAPEST
HONGRIE

PCT

WRITTEN OPINION

(PCT Rule 66)

Date of mailing *(day/month/year)*	29.03.2000
REPLY DUE	**within 3 month(s)** from the above date of mailing

Applicant's or agent's file reference	International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
68.002/BT	PCT/HU99/00035	04/05/1999	05/05/1998

International Patent Classification (IPC) or both national classification and IPC
G11B7/00

Applicant
OPTILINK AB et al.

1. This written opinion is the first drawn up by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

I	☒	Basis of the opinion
II	☐	Priority
III	☐	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☒	Lack of unity of invention
V	☐	Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☐	Certain document cited
VII	☒	Certain defects in the international application
VIII	☒	Certain observations on the international application

3. The applicant is hereby invited to reply to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also: For an additional opportunity to submit amendments, see Rule 66.4.
For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis.
For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 05/09/2000.

Name and mailing address of the international preliminary examining authority:
European Patent Office
D-80298 Munich
Tel +49 89 2399 - 0 Tx: 523656 epmu d
Fax. +49 89 2399 - 4465

Authorized officer / Examiner
Chaumeron, B

Formalities officer (incl. extension of time limits)
Gazzoli, M
Telephone No +49 89 2399 2815

I. Basis of the opinion

1. This opinion has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed".*):

Description, pages:

1-28 as originally filed

Claims, No.:

1-23 as originally filed

Drawings, sheets:

1/7-7/7 as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. This opinion has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation (Form PCT/IPEA/405) to restrict or pay additional fees, the applicant has:

- ☐ restricted the claims.
- ☒ paid additional fees.
- ☐ paid additional fees under protest.
- ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with for the following reasons

and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees:

3. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this opinion:

☒ all parts.

☐ the parts relating to claims Nos. .

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item VII

Certain defects in the international application

1.) Reference is made to the following documents:

D1: S. HVILSTED ET AL: " Side chain liquid-crystalline polyesters for optical information storage" OPTICS LETTERS, vol. 17, no.17, 1 September 1992, pages 1234-1236, New York, USA;
D2: WO-A-97/02563;
D3: Patent abstract of Japan, vol. 1995, no.6 , 31-07-1995 & JP-A-7065138 (10.03.1995) Dainippon Printing Co. Ltd. (*)

*: document not cited in the international search report. A copy of the document is appended hereto.

2.) The features of the preamble of **claim 1** as well as the first feature of the characterising portion of the claim ("using reflected transmission an polarisation holography with different write and read wavelengths") are known from D1 (see D1, page 1234, right-hand column last paragraph to page 1235, left -hand column first paragraph). Thus the requirement of Rule 6.3(b)(i) PCT is not correctly met.

3.)The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

4.) The applicant is kindly requested to indicate on which prior art document the two part form of **claim 9** is based.

5.) Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1,D2,D3 are not mentioned in the description, nor are these documents identified therein.

6.) It is recommended to use the usual phrase "characterised in that" instead of "characterised by that" in the claims drafted in the two part form format.

Re Item VIII

Certain observations on the international application

1.) In claim 1 the term 'thin' is not clear. One possibility to overcome this objection would be to redefine the term using the wording of the description of page 13, lines 12,13 (reference is also made to the PCT Guidelines for examination, Section IV part III-4.5).

2.) In claim 5 a recording medium is specified by making reference to the wavelength of an external laser beam. This leads to a doubt regarding the matter for which protection is sought. Therefore the claim lacks clarity. One possibility to overcome this objection would be either to claim a "holographic data storage system" instead of a "holographic recording medium" and to specify a writing light source and a reading light source, or to keep the original claim designation "holographic recording medium" and to indicate wavelength values in the claim.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
68.002/BT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/HU 99/00035	04/05/1999	05/05/1998

Applicant

OPTILINK AB et al.

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 5 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [X] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the drawings to be published with the abstract is Figure No. 2

   [ ] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [X] because this figure better characterizes the invention.

   [ ] None of the figures.

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-4,9-18

   Recording and reading information on a holographic recording medium using different write and read wavelengths, and corresponding apparatus

2. Claims: 5-8

   Holographic recording medium having a polarisation sensitive polymer material and a specific thickness

3. Claims: 19-23

   Method for coding information recorded on a holographic recording medium

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G11B7/00 G03H1/26 G11B7/12 G11B7/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G11B G03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim
A	S. HVILSTED ET AL: "Side-chain liquid-crystalline polyesters for optical information storage" OPTICS LETTERS, vol. 17, no. 17, 1 September 1992 (1992-09-01), pages 1234-1236, XP000293929 New York page 1234, column 2, paragraph 3 - page 1236, column 1, paragraph 1 ---	1,9,17
A	WO 97 02563 A (YENPLOY PTY. LTD.) 23 January 1997 (1997-01-23) page 1, line 4-7 page 2, line 16-20; figures 1-4 --- -/--	1,9,17

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 August 1999	

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chaumeron, B

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 671 073 A (DEMETRI PSALTIS ET AL) 23 September 1997 (1997-09-23) column 4, line 8 - column 7, line 34; figure 1 ---	1,9,17
A	US 5 566 387 A (DUANE S. DEWALD) 15 October 1996 (1996-10-15) column 4, line 17 - column 6, line 55; figures 1,2 -----	1,9,17

3

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 9702563	A	23-01-1997	AU	701056 B	21-01-1999
			AU	6294296 A	05-02-1997
			CA	2226268 A	23-01-1997
			EP	0836738 A	22-04-1998
US 5671073	A	23-09-1997	NONE		
US 5566387	A	15-10-1996	US	5481523 A	02-01-1996
			WO	9517748 A	29-06-1995

INTERNATIONAL SEARCH REPORT

International Application No
PCT/HU 99/00035

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G11B7/00 G03H1/26 G11B7/12 G11B7/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G11B G03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	S. HVILSTED ET AL: "Side-chain liquid-crystalline polyesters for optical information storage" OPTICS LETTERS, vol. 17, no. 17, 1 September 1992 (1992-09-01), pages 1234-1236, XP000293929 New York page 1234, column 2, paragraph 3 - page 1236, column 1, paragraph 1 ---	1,9,17
A	WO 97 02563 A (YENPLOY PTY. LTD.) 23 January 1997 (1997-01-23) page 1, line 4-7 page 2, line 16-20; figures 1-4 ---	1,9,17

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/HU 99/00035

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9702563 A	23-01-1997	AU 701056 B	21-01-1999
		AU 6294296 A	05-02-1997
		CA 2226268 A	23-01-1997
		EP 0836738 A	22-04-1998
US 5671073 A	23-09-1997	NONE	
US 5566387 A	15-10-1996	US 5481523 A	02-01-1996
		WO 9517748 A	29-06-1995

INTERNATIONAL SEARCH REPORT

International application No.
PCT/HU 99/00035

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Repon has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims: it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

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Date: 28. July 2000.

Your ref: PCT/HU99/00035

Our ref: 68.002/BT

FAX: 49-89-2399 4465

Total 10 pages

International Preliminary
Examining Authority
European Patent Office

München

Re.: First Written Opinion, mailed 29.03.2000
International Application: PCT/HU99/00035
Applicant: OPTILINK AB et al.
Title: System and method for recording of information on a holographic recording medium, preferably an optical card

Dear Sir/Madam,

As a Response to the first Written Opinion, Applicant respectfully submits amended pages 3a, 3b of the Description, and amended Claims 1-23, on pages 29-33, and requests the establishment of the International Preliminary Examination Report based on the amendments.

The attention of the Examiner is drawn to the following changes, using the numbering of the Opinion:

1, The amended pages 3a, 3b of the Description include a brief comment of the relevant prior art cited by the Examiner as D1 and D2. The document D3 was not considered relevant and therefore not cited.

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TELEPHONE (361) 342 4950 TELEFAX (361) 342 4323 POSTAL ADDRESS H-1369 BUDAPEST. P O Box 350 HUNGARY
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2, Claim 1 has been amended to transfer the known feature „polarisation holography with different write and read wavelengths is used". The new feature of the reflected transmission holography is supported by page 4, lines 10-20, page 13, line 16 - page 14, line 16.

3, Reference signs have been introduced in the claims, where appropriate.

4. It is respectfully submitted that the formulation of claim 9 is not based on any specific document. The features of the preamble may be combined from several documents, based on the knowledge of a person skilled in the art. Reference is made to the cited document US 5,671,073, , Figs 7A and 7B, which show several features of the invention, though this solution is not using polarisation holography. A principal optical setup for polarisation holography may be found in Fig. 3. of the publication „Side-chain liquid crystalline polyesters for information storage" by P.S. Ramanujam et al, in Polymers for Advance Technologies, Volume 7, pp. 768-776, 1996, John Wiley and Sons, Ltd. The features of the characterising part are intended to expose the most relevant features of the inventive arrangement.

5. See para 1. above

6. The claims have been changed to use the phrase „characterised in that"

Observation 1: Claim 1 have been amended with the phrase „with a holographic recording layer (33) having a thickness in the order of wavelength of the reading and recording light" instead of the „thin" holographic layer. This amendment is based on the disclosure of page 4, lines 1-2.

Observation 2: The preamble of Claim 5 was amended to include the feature „a holographic recording layer (33) sensitive to a reading and/or recording light having a given wavelength". It is believed that this amendment should alleviate the ambiguity of the feature „wavelength of the reading and/or recording light" in the characterising part. In this way it is clear that the properties of the recording layer may be understood by the person skilled in the art. This amendment is obvious in light of the whole description.

The amendments are perceived not to go beyond the original disclosure, and are therefore requested for acceptance.

Applicant is ready to discuss further amendments with the Examiner in an informal communication according to Rule 66.6 (b), if deemed necessary by the Examiner. Also, Applicant requests that the International Preliminary Examination Authority grant a further opportunity to submit amendments, if the Examiner finds that the claims presently on file do not satisfy the criteria set out in the Articles and Rules of the PCT.

Yours sincerely

on behalf of Applicant
Dr. Tamás Bokor, Patent Attorney
S. B. G. & K Patent Office

Encl.:
Amended description, pages 3a,3b (2 sheets)
Amended claims, pages 29-33 (5 sheets)
(3 copies sent with confirmation letter)

optical card. US patent No. 4,888,260 discloses another method for the preparation of a volume phase reflection hologram. Here, the volume phase reflection hologram is formed by a second off-axis hologram in the same recording medium. This method is not suitable for forming erasable and re-recordable holograms, and the optical system is very complicated. US patent No. 5,710,645 discloses a method and system for recording a grazing incidence hologram, which is supported on a substrate having a thin edge-illuminatable geometry, like an optical card. Theoretically, this system could be used for data storage as well, but again the edge-illumination demands very special mechanical and optical properties of the card carrying the hologram.

The document „Side-chain liquid crystalline polyesters for optical information storage", published in OPTICS LETTERS, vol. 17. no. 17, September 1992, pages 1234-1236, New York, US mentions the possibility of polarisation holographic recording in combination with different write and read laser wavelength. However, this document does not address the problem of distortion caused by the difference in the wavelengths.

The document WO-A-97/02563 discloses an optical system for holographic recording. This known system also includes lasers with a different read and write wavelength. The suggested data storage medium is a card with a thick (50μm) holographic storage layer. Different forms of holography are suggested, but polarisation holography is not mentioned. The write and read optics contain waveguide structures in combination with detector cells to read out the data, instead of traditional optical systems. The optical head detects the intensity modulation caused by the recorded holograms directly, and there is no imaging system between the storage medium and the optical head. Therefore, the problem of wavelength distortion is not addressed either. On the other hand, the disclosed complex waveguide head comprises expensive acousto-optical elements and other electro-

optical devices which require very sophisticated control and power supply systems. This optical head can not be manufactured in a cost-effective way with current technology.

Therefore, it is the object of the invention to provide a method and system for data storage based on reflection holography, where the holograms may be recorded and erased several times, preferably in an unlimited number of cycles, and where the holograms need to be accessed from one side only, both during writing and readout. Also, the holograms should be stored on an optical recording medium, preferably an optical card or disk that is easy to manufacture, and which tolerates normal daily wear, i. e. which is subjected to the same or similar treatment as a traditional plastic credit card or a floppy disk. It is a further object of the invention to provide a method and system for data storage where the read-write apparatus contains a relatively small, simple and cheap optical system. It is a further object to provide an optical recording method that ensures high data density and high data transfer rate, and at the same time allow efficient encoding or encryption of the data, and thereby provides enhanced security.

Summary of the Invention

According to the invention, this goal is achieved by a method, which uses a holographic write/read apparatus, and a recording medium, preferably an optical card, with a thin holographic recording layer. The holographic recording medium

Claims:

1. Method for the recording and reading of data on a recording medium (2), using a holographic recording medium with a holographic recording layer (33) having a thickness in the order of wavelength of the reading and recording light, the holographic recording medium being preferably an optical card (2), and holographic write/read apparatus (1) for the recording medium, wherein
the recording of the information is in the form of data pages stored as Fourier holograms recorded in a recording, and
reflected transmission and polarisation holography with different write and read wavelengths is used,
characterised in correcting the distortion during reading in the readout channel caused by the difference between the write and read wavelengths.

2. Method according to claim 1, wherein the wavelength distortion is corrected by optical and/or software means.

3. Method according to claim 1 or 2, wherein the holograms (61) are recorded as on-axis holograms.

4. Method according to any one of the claims 1 to 3, wherein the recording and reading is made with polarisation multiplexing and/or phase-code and/or rotational multiplexing.

5. Holographic recording medium, preferably an optical card (2), having a carrier substrate (31), a holographic recording layer (33) sensitive to a reading and/or recording light having a given wavelength, and a reflection layer (32) between the carrier substrate (31) and the recording layer (33), characterised in that the recording layer (33) is a polarisation sensitive polymer material, and the thickness of the

recording layer (33) is 0.5-2 times the wavelength of the reading and/or recording light.

6. Holographic recording medium according to claim 5, wherein the reflection layer (32) is a wavelength selective mirror reflecting on the read wavelength and transmitting or absorbing on the write wavelength.

7. Holographic recording medium according to claim 5 or 6, wherein the recording layer (33) is an azobenzene SCP layer.

8. Holographic recording medium according to any one of the claims 5 to 7, wherein the recording layer (33) is covered by a protective layer (34).

9. Apparatus for the writing and reading of a holographic recording medium, preferably an optical card (2), having a recording medium holding and/or positioning mechanism (4), movable or fixed read and write optics (9),
the write optics comprising a polarised writing light source (20), polarising selector means (23) for separating and/or combining the reference beam and the object beam, object beam modulating means (25), polarisation wave plate (24,35), an objective lens (27,47) for imaging the object beam onto a recording layer, and further the read optics comprising a polarised reading light source (21), and a polarising selector (23') and/or spatial filtering means for separating and/or combining the reference beam and the image beam, a light detector (29) and an objective lens (28,47) for imaging the image beam onto a light detector (29),
characterised in that the wavelength of the reading light source (21) is different from the writing light source (20), and
the read optics comprise wavelength distortion correcting means for correcting the distortion of the reconstructed image caused by the difference in the wavelength of the reading and writing light.

10. Apparatus according to claim 9, wherein the wavelength of the writing light source (20) is between 400-550 nm, and the wavelength of the reading light source (21) is between 600-700 nm.

11. Apparatus according to claim 9 or 10, wherein the wavelength distortion correcting means of the read optics comprise an aspherical plastic objective lens (48).

12. Apparatus according to any one of the claims 9 to 11, wherein the object beam and the reference beam in the read optics and/or the write optics have a common optical axis, and the polarising selector means comprise a polarisation selective beam splitter (23) and/or the spatial filtering means comprise a beam stop (36) for separating the reflected reference beam (18') from the reflected object beam (17).

13. Apparatus according to any one of the claims 9 to 12, wherein polarisation encoder means (26) are provided in the optical path of the reference beam (18).

14. Apparatus according to claim 13, wherein the polarisation encoder means are comprising a LCSLM.

15. Apparatus according to any one of the claims 11 to 14, wherein the read optics and the write optics have a common objective lens (47) for imaging the reference and object beams (18,16) onto a recording layer and for imaging the reflected object beams (17) onto the read detector (29).

16. Apparatus according to claim 15, wherein the common objective lens is an aspheric lens (48) for the correction of the wavelength distortion, the aspheric lens (48) having a central region (49) and an annular region (50) in its aperture, where

the central region (49) of the aspheric lens is tuned to the wavelength of the writing light source (20) for focusing the write object beam (17) onto the recording layer (33), and at the same time tuned to the wavelength of the read light source (21) for imaging the read object beam (17) onto the detector (29), and further the annular region (50) of the lens (48) is tuned to the wavelength of the read light source (21) for imaging the reflected object beam (17) onto the detector.

17. Holographic data storage system with a holographic recording medium (2) and a read/write apparatus (3) for the holographic recording medium (2), particularly with the recording medium according to claim 5 and for a read/write apparatus according to claim 9,
characterised in utilising reflected transmission and polarisation holograms with different read and write wavelength, together with distortion correction means (47) for correcting the distortion caused by the difference between the read and write wavelength.

18. The system according to claim 17, wherein the data storage capacity is multiplied by polarisation and/or phase code and/or rotational multiplexing.

19. Method for coding of the recorded information on a holographic optical recording medium, preferably an optical card (2), where the information is recorded in the form several discrete holograms (61) and/or subholograms recorded in different physical and/or logical recording locations on the optical recording medium (2), the holograms (61) containing data sets, where the sequence of the data sets together constitute the recorded information,
characterised in that the data sets are recorded in a random sequence of the recording locations.

20. The method according to claim 19, wherein the information is recorded in multiplexed holograms (61), and the logical recording locations are identified by the multiplexing address.

21. The method according to claim 20, wherein the information is recorded by polarisation holography using phase-code multiplexing, where one hologram (61) contains several phase-coded multiplexed holograms, and the logical recording locations are identified by the phase code address.

22. The method according to any one of the claims 19 to 21, wherein the location of the first data set is stored, and the location of the following data sets are stored in the previous data sets.

23. The method according to any one of the claims 19 to 22, wherein the random sequence of the data sets are stored and encrypted and/or made inaccessible for unauthorised users.

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
G11B 7/00, G03H 1/26, G11B 7/12, 7/24

A1

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P 98 01029 5 May 1998 (05.05.98) HU

(71) Applicant *(for all designated States except US)*: OPTILINK AB [SE/SE]; Soft Center, S–372 25 Rönneby (SE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: RAMANUJAM, P., S. [DK/DK]; Aegirsvej 5, DK–4000 Roskilde (DK). HVILSTED, Sören [DK/DK]; Grundtmannsvej 4, DK–2970 Hörsholm (DK). KOPPA, Pál [HU/HU]; Reáltanoda u. 16, H–1053 Budapest (HU). LŐRINCZ, Emőke [HU/HU]; Gombocz Zoltán u. 3, H–1118 Budapest (HU). RICHTER, Péter [HU/HU]; Mátyás u. 18, H–1093 Budapest (HU). SZARVAS, Gábor [HU/HU]; Zab u. 8, H–1033 Budapest (HU).

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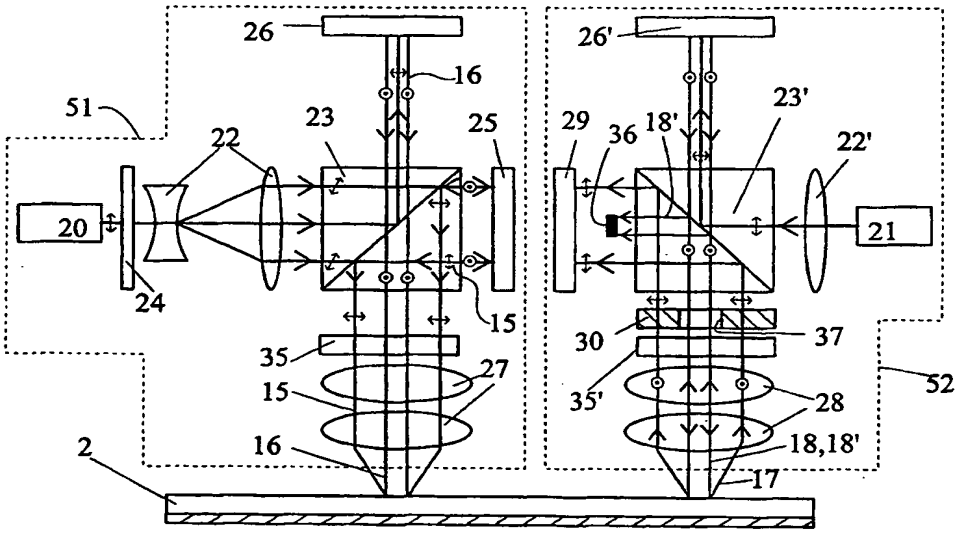
(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: SYSTEM AND METHOD FOR RECORDING OF INFORMATION ON A HOLOGRAPHIC RECORDING MEDIUM, PREFERABLY AN OPTICAL CARD



(57) Abstract

The invention relates to a method for the recording and reading of data with a holographic write/read apparatus onto a holographic recording medium with a thin holographic recording layer. The medium is preferably an optical card (2). The recording of the information is in the form of data pages stored as thin Fourier holograms (61). According to the invention, it is foreseen to use reflected transmission and polarisation holography with different write and read wavelengths, and to correct during reading the distortion in the readout channel caused by the difference between the write and read wavelengths. The invention further relates to an apparatus and system for performing the method. There is also disclosed a method of coding the recorded information.

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SYSTEM AND METHOD FOR RECORDING OF INFORMATION ON A HOLOGRAPHIC RECORDING MEDIUM, PREFERABLY AN OPTICAL CARD

Technical Field

The present invention concerns a method and apparatus for the recording and reading of data on a recording medium, preferably an optical card, by holography. The invention also relates to an apparatus for use with the method of the invention. The apparatus uses a holographic recording medium, and holographic write/read optical system. The recording medium is preferably an optical card. It has a thin holographic recording layer, wherein the recording of the information is in the form of data pages stored as thin Fourier holograms. The invention further relates to a method for coding of the recorded information on a holographic optical recording medium. In the method, the information is recorded in the form of several discrete holograms recorded in different physical and/or logical recording locations on the optical recording medium. Each hologram containing data sets and the sequence of the data sets together constitute the recorded information.

Background Art

The known optical memory cards provide approx. 4-6 MB of data on a credit card sized optical card, and the reader/writer units offer 30-10 KB/s data transfer rate. Writing speeds are normally slower than reading speeds.

Holographic recording is known for its inherent high data density, and therefore has been suggested for use in a data storage card. A number of solutions have been proposed for incorporating holograms into data storage cards, but the hologram is mostly used for authentication purposes, and not for data storage. Using holograms to store data on a credit-card sized data card involves several problems.

First, most holographic techniques require that the photosensitive medium storing the hologram be illuminated from both sides, either during recording or during

readout. Accordingly, the recording medium, preferably an optical card holding the holograms should have an optical-quality surface on both sides, and have constant thickness. These requirements are difficult to meet with a conventional plastic card. Second, for data storage application it is desirable to use a recording medium that may be erased and re-recorded. There are very few erasable optical materials that are suitable for holographic recording, the achievable signal-to-noise ratio is relatively low and high exposition energy is needed. Third, with every readout, the recorded holograms will be slightly erased. To ensure the stability of the recorded holograms, different reading and writing wavelength is required, but in this case the reconstructed image of the hologram is distorted so much, that high-density storage is not possible.

A known method of reflection holography is disclosed in the publication DE 195 34 501 A1., and in the publication "High density disc storage by multiplexed microholograms", SPIE Vol. 3109, pp. 239-244. In these solutions a method is suggested to create reflection holograms. It is suggested to apply a mirror under the recording layer during the recording phase, so that the object beam reflected from the mirror will act as reference beam. Thereby no separate optical path is needed for the reference beam. It is suggested to multiply the storage capacity by different forms of multiplexing. The holograms are reconstructed as volume reflection holograms. A disadvantage of the proposed solution is that the mirror must be removed during readout, which makes this system unfit for practical optical recording systems. Also, there is no suggestion to use this method with an optical card.

Another form for reflection holography is disclosed in the US patent No. 5,633,100, which patent teaches a process for forming a volume reflection hologram. This known solution also require the use of a reference beam that is incident on the opposite surface of the photosensitive medium, so the solution is not practical for an

optical card. US patent No. 4,888,260 discloses another method for the preparation of a volume phase reflection hologram. Here, the volume phase reflection hologram is formed by a second off-axis hologram in the same recording medium. This method is not suitable for forming erasable and re-recordable holograms, and the optical system is very complicated. US patent No. 5,710,645 discloses a method and system for recording a grazing incidence hologram, which is supported on a substrate having a thin edge-illuminatable geometry, like an optical card. Theoretically, this system could be used for data storage as well, but again the edge-illumination demands very special mechanical and optical properties of the card carrying the hologram.

Therefore, it is the object of the invention to provide a method and system for data storage based on reflection holography, where the holograms may be recorded and erased several times, preferably in an unlimited number of cycles, and where the holograms need to be accessed from one side only, both during writing and readout. Also, the holograms should be stored on an optical recording medium, preferably an optical card or disk that is easy to manufacture, and which tolerates normal daily wear, i. e. which is subjected to the same or similar treatment as a traditional plastic credit card or a floppy disk. It is a further object of the invention to provide a method and system for data storage where the read-write apparatus contains a relatively small, simple and cheap optical system. It is a further object to provide an optical recording method that ensures high data density and high data transfer rate, and at the same time allow efficient encoding or encryption of the data, and thereby provides enhanced security.

Summary of the Invention

According to the invention, this goal is achieved by a method, which uses a holographic write/read apparatus, and a recording medium, preferably an optical card, with a thin holographic recording layer. The holographic recording medium

may be in the form of an optical disk or tape as well. The term "thin" means that the layer thickness is in the order of the light wavelength, and the holograms recorded may not be regarded as traditional volume holograms, so that the recording of the information is in the form of data pages stored as thin Fourier holograms.

According to the invention, reflected transmission and polarisation holography with different write and read wavelengths are used and further, the distortion is corrected during reading, which distortion is caused by the difference between the write and read wavelengths.

The use of reflected transmission holography is a key element in the recording method of the invention. It has been proposed to overcome the problems involved with the illumination of or accessing of the hologram from two sides, either during recording or readout. Therefore, it is suggested to use a form of reflection holography, which will be referred to hereinafter as reflected transmission holography. In accordance with the invention, in this holographic recording method the recording layer is relatively thin, and there is a reflective layer under the recording layer. The readout of the hologram is performed in the transmission mode, but the transmitted object wave is reflected from the reflective layer, propagates through the recording medium, and is detected on the same side from which the reference wave arrives.

According to the invention, for the method it is suggested to use a holographic recording medium, such as a memory card having a carrier substrate, a holographic recording layer sensitive to light, and a reflection layer between the carrier substrate and the recording layer. In the recording medium of the invention the recording layer is a polarisation sensitive polymer material, and the thickness of the recording layer is 0.5-2 times the wavelength of the reading and/or recording light.

The method is realised with an apparatus for the writing and reading of a holographic recording medium, preferably an optical card, having a recording medium holding and/or positioning mechanism, movable or fixed read and write optics, where the write optics comprising a polarised writing light source, a polarising selector means for separating and/or combining the reference beam and the object beam, object beam modulating means, a polarisation wave plate, an objective lens for imaging the object beam onto a recording layer, and further the read optics comprising a polarised reading light source, and a polarising means and/or spatial filtering means for separating and/or combining the reference beam and the image beam, a light detector and an objective lens for imaging the image beam onto a light detector. In the apparatus according to the invention, the wavelength of the reading light source is different from the writing light source, and the read optics comprise wavelength distortion correcting means for correcting the distortion of the reconstructed image caused by the difference in the wavelength of the reading and writing light.

The invention also includes a holographic data storage system with a holographic recording medium, and a read/write apparatus for the holographic recording medium, particularly with the recording medium and for the read/write apparatus according to the invention. The proposed system utilises reflected transmission and polarisation holograms with different read and write wavelengths, together with distortion correction means for correcting the distortion caused by the difference between the read and write wavelengths.

According to the invention, there is also provided a method wherein the wavelength distortion is corrected by optical and/or software means. In the most preferred embodiment the correction is performed by an appropriately designed lens system and the holograms are recorded as on-axis holograms, using the advantages of the polarisation recording.

It is suggested that the recording and reading is made with polarisation multiplexing and/or phase-code and/or rotational multiplexing. Especially the so-called deterministic phase-code multiplexing is foreseen, which may increase capacity by an order of magnitude, and also contributes to the encryption of the data, as will be shown below.

In a special embodiment of the holographic recording medium of the invention the reflection layer is a wavelength selective mirror reflecting on the read wavelength and transmitting or absorbing on the write wavelength. This arrangement greatly improves the sensitivity of the recording.

In a further embodiment, the holographic medium is a write-once or erasable-rewritable holographic medium, preferably a side-chain polyester (SCP), most preferably azobenzene SCP. Azobenzene SCP is a novel holographic material, allowing the recording of high-density data storage using polarisation holography.

Advantageously, the wavelength of the writing light source of the apparatus of the invention is between 400-550 nm, and the wavelength of the reading light source is between 600-700 nm. Such light sources are readily available in the forms of laser diodes, allowing the construction of small and robust optical read/write systems. Other light sources, such as solid state lasers are also considered, because they provide higher energy levels.

In the most preferred embodiment, the wavelength distortion correcting means of the read optics comprises an aspherical plastic objective lens.

It is contemplated that the object beam and the reference beam in the read optics and/or the write optics have a common optical axis, and there is provided a

polarisation selective beam splitter in combination with a polarisation wave plate and/or a beam stop for separating the reflected reference beam from the reflected object beam. This is feasible, because the polarisation holography technique suggested allows the separation of the reference beam from the object beam, and the SNR of the readout is high.

Advantageously, polarisation encoder means, especially liquid crystal spatial light modulators (LCSLMs) are provided in the optical path of the reference beam. These devices allow the use of phase code multiplexing.

It has been found practical and feasible for the read optics and the write optics to have a common objective lens for imaging the reference and object beams onto a recording layer and for imaging the reflected object beams onto the read detector. Thereby the optical system may be compact and lightweight, and the positioning system is simpler. Also, direct readout after recording is possible, practically without any delay.

In an especially preferred embodiment of the apparatus, the common objective lens is an aspheric lens for the correction of the wavelength distortion, where a central region of the aspheric lens is tuned to the wavelength of the writing light source for focussing the write object beam onto the recording layer and at the same time tuned to the wavelength of the read light source for imaging the read object beam onto the detector, and further the annular region of the lens is tuned to the wavelength of the read light source for imaging the reflected beam onto the detector.

In a further preferred embodiment of the optical system of the invention, the holographic record and readout optics comprise means for reading and/or writing multiplexed holograms. For example, using deterministic phase encoding multiplexing, the information density of a hologram may be increased in theory by

several magnitudes. In a practically viable system, multiplexing with a factor of five to thirty is possible.

Using the advantageous properties of the holographic recording method and the recording medium of the invention, it is also proposed to implement a novel method for the coding of the recorded information on the holographic optical recording medium. The method comprises the recording of the information in the form of several discrete holograms and/or subholograms recorded in different physical and/or logical recording locations on the optical recording medium, preferably an optical card. These holograms or subholograms contain data sets, where the sequence of the data sets together constitute the recorded information. According to the inventive method, the data sets are recorded in a random sequence of the recording locations. If the sequence of the recording is not readily known, the access to the data is effectively blocked. The method requires relatively little excess memory capacity, but at the same time it is very effective.

It is also contemplated that the information is recorded in multiplexed holograms, and the logical recording locations are identified by the multiplexing address. In the most preferred embodiment, the information is recorded by polarisation holography using phase-code multiplexing, where one physical hologram volume contains several phase-coded multiplexed subholograms. The logical recording locations are identified by the phase code address.

In a further improved implementation, the location of the first data set is stored, and the location of the following data sets are stored in the previous data sets. It is especially foreseen that the physical recordings follow each other in an ordered sequence, but that the phase code addresses change randomly. Thereby the readout data rate can be maintained at a high level, but the encoding is still ensured. In an optional preferred realisation of the method, the random sequence of the data sets is stored and encrypted and/or made inaccessible for unauthorised users. This latter solution may facilitate the faster readout of the data.

Brief Description of Drawings

The invention will now be described in more detail herein below with reference to the accompanying drawings, which, by way of example only, illustrate preferred embodiments of the methods, apparatus and the system according to the invention, together with the optical recording medium.

In the drawings

Fig. 1. shows a schematic diagram of the functional blocks of the optical storage system,

Fig. 2 shows a schematic diagram of the holographic read/write optics of the system and apparatus according to a preferred embodiment of the invention,

Fig. 3 shows a schematic diagram of the holographic read/write optics of the system and apparatus according to another preferred embodiment of the invention,

Fig. 4a-b shows a schematic cross-section of the optical recording medium, in this case an optical card, utilised in the optical system of the invention, and illustrates the principle of the holographic recording method in accordance of the invention,

Fig. 5 shows the layout of the data on the optical card of the invention, and illustrates the method used for encoding of the information,

Fig. 6a-b shows the side and top view of the means for the correction of the wavelength distortion in the read/write optics of Fig. 3,

Fig 7 shows a schematic diagram of the mechanical positioning system of the apparatus according to the invention,

Fig. 8 is a schematic diagram of the holographic read/write optics of the system and apparatus according to a modified embodiment of the invention.

Best Mode for Carrving out the Invention

Fig. 1 shows the block diagram of the optical storage system 1 of the invention. The holographic optical storage system 1 comprises the optical recording medium. The medium is preferably an optical card 2, which is normally fixed on the card positioning unit 4. It must be emphasised that instead of the optical card, an optical disk or tape is also suitable to realise the invention. The optical card 2 is read and written (recorded) by the card read/write optics 3. The functions of the optical storage system 1 are controlled by the main controller 5, which is practically a microprocessor. The main controller 5 is controlling the data processor 6 and the synchronising circuit 8, and further the positioning controller 9. The main controller 5 is also connected to the interface 7. Data input and output are effected through the interface 7, and the data are processed by the data processor 6. Synchronising circuit 8 synchronises the read/write functions of the read/write optics 3 with the positioning functions of the positioning controller 9.

Fig. 2 illustrates the optical system of the holographic read/write optics 3 of Fig. 1. In the embodiment of Fig. 2, the holographic read/ write optics 3 has a write optics part 51 and a read optics part 52. These two parts may be fully separated, having a separate moving system, but in a practical embodiment the two parts are moved together with a common positioning system. In another preferred embodiment, the write optics part 51 and a read optics part 52 are fixed, and the optical card 2 is positioned relative to the optics by the positioning mechanism 4 of Fig. 1 (see also Fig. 7.).

The write optics part 51 comprises the write laser 20, operating in the visible blue-green region, around 532 nm. The write laser 20 is preferably a semiconductor laser, but other types of laser are also suitable. However, the laser used for the recording must have a sufficient coherence length, i. e. longer than the path difference

between the object beam and the reference beam. The beam of the write laser 20 is directed through the half-wave-plate 24, the beam shaping optics 22 and the beamsplitter 23. The beam-shaping optics 22 transforms the Gaussian intensity distribution of the laser 20 into a square distribution in a known manner. The purpose of this transformation is to provide uniform illumination in the whole object space, i. e. on the object SLM (Spatial Light Modulator) 25. The polarising beamsplitter 23 separates the beam into the object beam 15 and the reference beam 16. After the polarising beamsplitter 23 the object beam 15 is transversely polarised, and the reference beam 16 is parallel polarised, relative to the plane of Fig. 2. The reference beam 16 is sent towards the reference SLM 26. The reference beam 16 is reflected from the reference SLM 26, and thereby the polarisation will change to transverse polarisation. The reference beam 16 is further directed through the beamsplitter 23, another quarter wave-plate 35 and then falls on the surface of the optical card 2 through the objective lens 27, which will be described below. After passing through the quarter wave-plate 35, the linear polarisation of the reference beam 16 will change to a circular polarisation.

After leaving the beamsplitter 23 the object beam 15 falls on the object SLM 25, with transverse polarisation. From the object SLM 25 the object beam 15 is deflected back towards the optical card 2, through the beam splitter 23, and the quarter wave-plate 35. Due to the reflection on the object SLM 25, the object beam 15 will be parallel polarised when entering and leaving the beam splitter 23 for the second time. Again, the orthogonal linear polarisation of the object beam is transformed into an orthogonal circular polarisation after the quarter wave-plate 35, but the rotation direction of the object beam 15 is opposite to the rotation direction of the reference beam 16. Finally, the object beam 15 falls on the surface of the optical card 2 through the same objective lens system 27, with other words, the reference beam 16 and the object beam 15 has a common optical axis to and from the optical card 2. This configuration of the optical system is denoted as an on-axis

configuration. The object beam 15 and the reference beam 16 are modulated by their respective spatial light modulators 25 and 26, as will be described below. The SLMs 26 and 25 are preferably LCD devices, with 1024x1024 or 512x512 pixel segments, where the light reflecting properties of the individual segments may be controlled individually by a suitable circuit, in the invention the data processing circuit 6. The object SLM 25 is encoded with the data, while the reference SLM 26 is encoded with the phase address. With this embodiment, the object SLM 25 is a device that modulates the amplitude (intensity) of the transmitted light, but other types of SLM devices are also contemplated for use in the apparatus of the invention. E.g. matrix polarisation modulators are also applicable, where the polarisation angle may be controlled. As will be discussed below, the reference SLM 26 is a polarising SLM, which is capable of adding a π phase delay to the reference beam 16. The object beam 15 and the reference beam 16 are imaged on the optical card 2 by a suitable objective lens system, preferably by Fourier transform lenses, here symbolised with the lens system 27. It is understood that other, presently not discussed optical components, like lenses, diaphragms, mirrors, etc. may also be used, in order to get a suitable beam shape at the SLM 26 and 25 and on the surface of the optical card 2. Particularly, a known focus and tracking servo optics and mechanism is also foreseen to focus the object beam 15 and the reference beam 16 on defined locations of the surface of the optical card 2.

With the embodiment of the read/write optics 3 shown in Fig. 2, the detection of the holograms on the optical card 2 is done with the read optics part 52. The read optics part 52 is similarly configured to the write optics 51, but the read laser 21 is a red laser. The read laser in this embodiment operates in the visible red region, between 600-700 nm, and is preferably another semiconductor laser or LED, or a He-Ne laser. Accordingly, the wave plate 35' is tuned for the wavelength of the read laser. Instead of the object SLM 25, there is a CCD detector 29. The hologram is imaged

on the CCD detector 29 with suitable imaging optics, preferably Fourier transform lenses, here illustrated with the objective lens 28.

The CCD detector 29 reads out the data stored in the hologram, which contains the bitmap image of the object SLM 25.

The recorded information is in the form of data pages stored as thin Fourier holograms. This means that the holograms may not be treated as traditional volume holograms. However, the holograms are enough thick, so their thickness can not be neglected either. These holograms in accordance with the invention represent an intermediate case, where the diffraction pattern is between the so-called Bragg diffraction valid for thick gratings, and the diffraction valid for infinitely thin gratings. The layer thickness used in the invention is practically between 300 nm and 3000 nm, which means that the resulting diffraction pattern is that of a finite layer thickness, with an appreciable wavelength and angle selectivity, but that these do not reach the selectivity of thick holograms.

According to the invention, the holographic recording is made by reflected transmission holography. The principle of this holographic recording method is explained with reference to Figs. 4a-b. Fig. 4a-b shows the cross-section of the optical card 2 and the reflective layer 32 underneath the recording layer 33. The recording layer 33 is relatively thin, and the reflective layer 32 is a wavelength selective layer, which reflects light on the readout wavelength, but absorbs (or alternatively transmits) light on the write wavelength. During recording (see Fig. 4a), the hologram 61 is created in the recording layer 33 of the card 2 by the polarisation interference pattern between the reference beam 16 and the object beam 15. In Fig. 4a-b the incident and reflected reference beams 18,18' are shown at an angle to each other for the better illustration of the reading process, but it must be pointed out that in reality the incident and reflected reference beams are substantially parallel, and have a common optical axis, at least in the preferred embodiments shown in the description. On the contrary, the object beams 15, 17 and

the reference beams 18,18' are indeed at a small angle to each other, although they still have a common axis.

During readout (see Fig. 4b), the incident reference beam 18 generates an object beam, which reproduces the information content of the original write object beam 15. The reproduced object beam would normally exit from the hologram 61 as transmitted object beam 19. But this transmitted object beam 19 is reflected on the reflective layer 32, propagates through the recording layer 33 one more time, and exits from the recording layer 33 as the reflected object beam 17. Of course, the reference beam 18 is also reflected as reflected reference beam 18', but this latter may be separated from the reflected object beam 17, using the polarisation properties and the different diffraction of the beams, as will be shown below.

As explained above, in the reflected transmission holography process in accordance with the invention, the readout of the hologram is performed in the transmission mode, but the transmitted object wave is reflected from the reflective layer, propagates through the recording medium, and is detected on the same side from which the reference wave arrives.

The holographic recording process utilised in the invention is the so-called polarisation holography. Polarisation holographic recording is accomplished by two plane waves having mutually orthogonal polarisation. In this type of recording the resulting light field is not modulated by intensity but only by polarisation. The induced optical anisotropy (dichroism or birefringence) is spatially modulated in accordance with the polarisation modulation of the recording light field, i.e., a polarisation holographic grating is recorded. The various possibilities for recording polarisation holographic gratings are known. It has also been shown that the diffraction efficiency (η) depends on the type of polarisation interference pattern, which forms the basis of the polarisation multiplexing. This is based on the fact that at sufficiently large values of photoinduced anisotropy it is feasible to record polarisation gratings with high efficiency, up to 25% for amplitude modulation and

up to 100% for phase modulation. When the recording is accomplished with two orthogonal circularly polarised waves, η is strongly dependent on the ellipticity of the reconstructing wave. By varying the ellipticity, η can vary from 0 to its maximum value. If the object and reference waves have parallel polarisations an ordinary intensity interference pattern results, i.e., the light field intensity is sinusoidally modulated. When the two waves have mutually orthogonal polarisations, the intensity of the resultant light field is constant and only its polarisation is periodically spatially modulated in accordance with the change of the phase shift between them producing a polarisation interference pattern. Both interference effects may be recorded with suitable materials. In the embodiments of the apparatus shown in Figs. 2 and 3, it is contemplated to utilise both effects. In the preferred version the object SLM 25 provides intensity modulation, but the reference beam 16 and the object beam 15 are also orthogonally polarised, to improve the readout SNR.

During the holographic recording in a photoanisotropic material the polarisation interference pattern is recorded as a spatially modulated optical anisotropy.

In the preferred realisation of the method of the invention, a so-called Side Chain Azobenzene Polyester (SCP) is used. In the recording process the molecules of the recording medium, e. g. a SCP compound, are aligned according to the polarisation of the incident light beam. The writing process utilises blue or green light, and the readout of the hologram is effected with red light. The recording process in e. g. azobenzene SCP material is described in detail in the publication "Side-chain Liquid Crystalline Polyesters for Optical Information Storage", in: Polymers for Advanced Technologies, Vol. 7, pp. 768-776., which is herewith included by reference. Similar materials suitable for holographic recording are also known, and may be used advantageously. The principles of polarisation holography are described in the publication "Polarisation holography. 1: A new high-efficiency organic material with reversible photoinduced birefringence", Appl. Opt., Vol. 23, No. 23, 1

December 1984, pp. 4309-4312, and the publication "Polarisation holography. 2. Polarisation holographic gratings in photoanisotropic materials with and without intrinsic birefringence", Appl. Opt., Vol. 23, No. 24, 15 December 1984, pp. 4588-4591. These latter are also included by reference. An important feature of the polarisation holography is that if the reference beam 16 and the reflected object beam 15 are chosen to be orthogonally polarised, then they may be completely separated by a polarising element. This results in outstanding signal-to-noise ratio (SNR). As shown in Fig. 2, the originally elliptic polarised beam of the write laser 20 and the read laser 21 are transformed into a parallelly polarised object beam 15 and a transversally polarised reference beam 16 (the plane of reference is the plane of Fig. 2.) by the wave-plate 35, and the polarising beam splitter 23. Upon readout, the reflected object beam 17 is separated from the reflected reference beam 18' with the help of polarising means and spatial filtering means. The polarising means and the spatial filtering means in this case include a half-wave plate 30 and a beam stop 36. The reflected object beam 17 is transversely polarised after passing through the half-wave plate 30. The central part of the half-wave plate 30 is provided with an aperture 37 for the reference beam 18. Before the detector 29 there is a centrally positioned beam stop 36, to filter out the reflected reference beam 18' which passes through the aperture 37 and partly reflects from the beam splitter 23' towards the detector 29. The beam stop 36 also filters out the reference beam 18 coming directly from the read laser 21. However, due to the difference in the write and read wavelengths, the reflected object beam 17 will diffract from the hologram on the holographic card 2 at a small angle to the reflected reference beam 18'. This small difference in the diffraction allow the spatial filtering of the reflected object beam 17 from the reflected reference beam 18'. As will be shown below, the objective lens 28 will keep the reflected object beam 17 spatially separated from the reflected reference beam 18', but at the same time it will image the reflected object beam 17 onto the peripheral parts of the detector 29, providing image correction on the object beam 17.

It must be noted that the diffraction efficiency also increases, if the polarisation technique is used together with the reflected transmission recording method. This is due to the fact that the polarised reference beam will phase shift with π on the interface layer of a reflective layer 32. That would mean that with a circularly polarised beam the direction of rotation will change to the opposite, but at the same time the propagating direction of the beam also reverses. The result will be that the beam will diffract in the same directions when travelling back through the recording layer.

Returning to Fig. 2, the read objective lens 28 is designed to correct the distortion of the readout. This distortion results from the wavelength difference between the laser 20 and the laser 21. Because of the on-axis configuration of the optical system, the distortions will be axially symmetric, and therefore they may be corrected by an appropriately designed aspheric lens, acting as the objective lens 28. This distortion is less significant for central rays and more significant for the rays close to the edge of the image space. Since the central rays in the readout optics 52 are reserved for the reference beam 18, the peripheral parts of the objective lens 28 need to be tuned to the object beam 17 only.

Fig. 4a-b are a schematic cross-sections of the optical recording medium. Here the recording medium is an optical card 2 used in the optical storage system 1 of the invention. The optical card 2 has a relatively thick - 0,5-1 mm - plastic base plate 31, made of a suitable plastic material, e. g. polycarbonate or PVC. A wavelength selective reflective layer 32 with an approximate thickness of 100 nm is coated on the base plate 31 with vacuum evaporation, sputtering or other suitable process. The purpose of the reflective layer 32 is to reflect during readout the object beam transversing the recording layer 33. Therefore, the reflective layer 32 must be reflecting the readout wavelength, but should advantageously be non-reflecting on

the write wavelength. It is desirable to suppress reflection of the writing beams, so that no disturbing interference results from the reflection of the reference beam 16 and the object beam 15 during writing. The recording layer 33 above the reflecting layer 32 is protected from mechanical and chemical effects by a protective layer 34.

Fig. 5. is a top view of the optical card 2, seen from the recording side, i. e. from the side of the protective layer 34. Though there is nothing in the way for providing a storage surface on both sides of the optical card, in practice only one side is used for data recording, while the other side is provided with written information legible with the naked eye, i. e. a short informative text about the type of the optical card. The recording on the optical card 2 is made in the form of very small holograms 61, each with a square form and the size of approx. 0.8 x 0. 8 mm^2. In Fig. 5 several other holograms 61i, 61j, 61k are shown, which all have the same structure as hologram 61. The holograms 61 are spaced approx. 200 microns apart from each other, and between them there is provided positioning markers 62 and 63, and eventually identifying markers 64. One set of markers 62 is used for positioning in the X direction, while the other set of markers 63 are used to align the read/write optics in the Y direction. The identifying markers 64 may contain information about the position of the hologram 62 on the optical card 2, and may also contain information about the type of the hologram 62.

Fig. 3. shows a modified version of the write/read optics of the invention presented on Fig. 2. This optical system combines the write optics part 51 and the read optics part 52 into a common unit. The basic configuration contains all the elements of the write optics 51, and the optical path of the write object beam and the write reference beam is principally the same. Accordingly, the combined read/write optics of Fig. 3 comprises the write laser 20, operating in the visible blue-green region, around 532 nm. The read laser operates in the visible red region, approximately at 630 nm, and is preferably another semiconductor laser or LED, or a He-Ne laser. The beam of

the write laser 20 is directed through the half-wave-plate 24, the beam shaping optics 22 and the beamsplitter 23. The light of the read laser 21 is inserted into the optical system through the neutral beam splitter 41. The beam-shaping optics 22 and 22' transform the Gaussian intensity distribution of the laser 20 and 21 into a square distribution. During writing, the beamsplitter 23 separates the beam into the object beam 15 and the reference beam 16. The reference beam 16 is sent through the beam splitter 41 towards the reference SLM 26. The reference beam 16 is reflected from the reference SLM 26 back through the beam splitter 41, the beamsplitter 23, a quarter wave-plate 45 and falls on the surface of the optical card 2 through the objective lens system 47, which will be described below. It is necessary to compensate the delay caused by insertion of the neutral beamsplitter 41 in the optical path of the reference beam 16. Therefore, an additional element must be added in the combined read/write optics 3. This is the compensator block 43, which provides the necessary delay in the optical path of the object beam 15. It must be noted that the quarter wave-plate 45 of the embodiment of Fig. 3 may be electronically controlled, so that it can be adjusted to the wavelength of the write or read beam. Alternatively, the quarter wave-plate 45 may be tuned to the wavelength of the read laser or the write laser, and the noise resulting from the difference of the wavelengths may be ignored or suppressed by appropriate means.

After the beamsplitter 23 the object beam 15 falls on the object SLM 25 through the compensator block 43. From the object SLM 25 the object beam 15 is reflected back towards the optical card 2, through the compensator block 43, the beamsplitter 23, and the quarter wave-plate 45. The object beam 15 falls on the surface of the optical card 2 through the same objective lens 47, so that the reference beam 16 and the object beam 15 have a common optical axis to and from the optical card 2. Hence, the combined read/write optics 3 is also built up with an on-axis configuration. The object beam 15 and the reference beam 16 are modulated by their respective spatial light modulators 26 and 25, similarly to the case with the separate read and write

optics parts 52 and 51. The object beam 15 and the reference beam 16 are imaged on the optical card 2 by an objective lens system 47. Other optical components, like lenses, diaphragms, mirrors, etc. may also be used, in order to get a suitable beam shape at the SLM 26 and 25 and on the surface of the optical card 2. The functioning of the objective lens system 47 is described in detail with reference to Fig. 6a-b.

Returning to Fig. 3, readout of the holograms is made with the read laser 21. The beam of the read laser 21 is coupled into the optics through the neutral beam splitter 41, and reflected toward the reference SLM 26. From the reference SLM 26 the reference beam 18 is reflected towards the optical card through the neutral beam splitter 41, the polarising beam splitter 23, the quarter wave-plate 45 and the same objective lens 47 which is also used for writing.

The incident reference beam 18 will diffract on the hologram on the optical card 2, and the reflected object beam 17 will be generated. Detection of the holograms on the optical card 2 is done with the CCD detector 29. The reflected object beam 17 is reflected towards the CCD detector 29 by the neutral beam splitter 41. During readout the electronically controllable wave plate 45 is tuned to the wavelength of the read laser 21. As with the optical system shown in Fig. 2, the reflected object beam 17 is separated from the reflected reference beam, but in this case only with spatial filtering. The spatial filtering is accomplished by the beam stop 36 positioned before the central area of the detector 29.

Referring to Fig. 6a-b, the principle of the wavelength distortion correction means according to a preferred embodiment is shown. In the embodiment of Fig. 2 and 3, the wavelength distortion correction means are embodied by the objective lens system 28 and the objective lens system 47. The function of the objective lens systems 28 and 47 is explained with reference to Fig. 6a, with the help of a

simplified scheme of the optical setup similar to that in Fig. 3. The objective lens system 47 of Fig. 3 consists of one or more aspherical plastic lenses, or aspherical glass lenses. At least one aspheric lens 48 comprises a central region 49 and an annular region 50 in its useful aperture. The aperture with the central region 49 and the annular region 50 is shown in Fig. 6b. As shown in Fig. 6a, during recording, the useful cross-section of the object beam 15 passes through the annular region 50, while the reference beam 16 passes through the central region 49 only. During readout, the read reference beam 18 will be confined to the central region 49, but the reflected transmission beam, i. e. the reflected object beam 17 will diffract in greater angle, because its wavelength is longer. Therefore, a small fraction of the reflected object beam 17 will pass through the central region 49 and the remaining larger fraction will pass through the annular region 50. Accordingly, the annular region 50 is shaped so as to compensate the wavelength distortion of the reflected object beam 17, and to provide a distortion-free image of the hologram 61 on the CCD detector 29. The shape of the central region 49 is formed so as to provide an acceptable imaging for the reference beams 16 and 18, both on the reading and the writing wavelengths. Of course, this will be a compromise between the optimal lens shapes for ideal imaging, so both beams will remain distorted to a small extent. But this distortion is tolerable, because in the central region 49 the angles of incidence are smaller than in the annular region 50.

It must be noted that the reference SLM 26 may be substituted with a mirror as well, both in the combined optics 3 of Fig. 3 and in the separate read and write optics parts 52 and 51 of Fig. 2. The purpose of the reference SLMs 26 is to allow the possibility of the so-called multiplexing using deterministic phase encoding. This method is described in the publication "Volume hologram multiplexing using a deterministic phase encoding method", Opt. Comm. 85 (1991), pp. 171-176. In this multiplexing method a liquid crystal spatial light modulator (LCSLM), in our case the reference SLM 26 is placed in the way of the reference beam. Each pixel of the

reference SLM 26 may be switched into two positions: either it adds π to the phase of the incoming beam, or it leaves the phase unchanged. In this way different reference wavefronts can be produced. The set of adjustable phases for a given reference beam represents the address of the corresponding object. It may be shown that during the reconstruction process a given reference beam will only reconstruct its own corresponding object beam, but the detected signal intensity will be lower. The number of independently recordable subholograms within one physical hologram is equal to the number of different phase addresses. Of course, because of the decrease in the signal intensity, the SNR of the recorded subholograms will decrease as well, so there is a practical limit to the multiplexing. It must be noted that the conditions for multiplexing are better for thicker holograms, but with thicker holograms the difference of the read and write wavelengths will cause larger distortions at the edges of the object space.

It has turned out that phase-code multiplexing technique works well for thin holograms. The number of multiplexed holograms can be increased by increasing the pixel number of the LCSLM. In order to minimize crosstalk, the different phase codes must be investigated, and those with the least crosstalk may be selected for practical purposes. The main factor that restricts the maximum number of multiplexed subholograms is the diffraction limited spot size of an LCSLM pixel. The number of the practically achievable multiplexed subholograms is approximately 5 to 30.

Beside the above described phase encoding, the so-called polarisation multiplexing technique may be used as well, if the optical setup is not with an on-axis configuration, but the reference and object beams are at an angle to each other.
It is known that for the case of recording with two orthogonal circularly polarised waves, the diffraction efficiency is strongly dependent on the polarisation of the reconstructing wave, particularly on its ellipticity. It is possible to control the

readout wave ellipticity with a $\lambda/4$ plate. The maximum value of the diffraction efficiency η in the +1 order is reached when the polarisation of the reconstructing wave coincides with that of the reference wave during the recording and falls to zero at orthogonal polarisation. At the same time the change of η in the -1 order is described by a similar relation, shifted at 90°; when η is at its maximum in the +1 order, in the -1 order it is equal to zero and vice versa. Therefore, the polarisation multiplexing method is the following:

- Take the first exposure with left-hand circular polarisation reference beam ('A' hologram)
- Take the second exposure with right-hand circular polarisation reference beam ('B' hologram)
- If we use left-hand circular polarisation read-out beam then the diffraction efficiency of the 'A' hologram will be maximum and the diffraction efficiency of the 'B' hologram will be minimum and we will reconstruct the 'A' hologram while the overlapping of the 'B' hologram will be minimum.

- If we use right-hand circular polarisation read-out beam then we will reconstruct the 'B' hologram while the overlapping of the 'A' hologram will be minimum.

Accordingly, the sensitivity of η to the polarisation of the recording beam makes it possible to double the information capacity of the recording. It is straightforward that in the optical recording method of the invention, the polarisation multiplexing could be combined with deterministic phase encoding multiplexing. The appropriate phase encoding of the SLM 26 is controlled by the data processor 6.

In a practical system using the information storage method of the invention a five to thirtyfold phase multiplexing is contemplated. Polarisation multiplexing necessitates

additional optical or mechanical elements to rotate the polarisation planes of the object and reference beams, and the polarising elements.

Such a system is also feasible, though the involved number of the mechanical and optical elements would make the system more complicated than the demonstrated preferred embodiments. In theory wavelength multiplexing is also possible, but the SCP materials inherent sensitivity to the write and read wavelengths makes this solution impractical.

A further possibility is the use of rotational multiplexing, i. e. coupling several object SLM areas successively to the optical system, as if the object SLM-s were rotated around the axis defined by the reference beam and the hologram on the optical card. True mechanical rotation or displacement of the object SLM-s is also possible.

Fig. 7 is a schematic diagram of a possible mechanical construction of the optical system 1 of the invention. The optical system 1 has two main mechanical components, the read/write optics 3 and the card positioning mechanism 4. The read/write optics 3 comprises the holographic read/record optics and the fine servo. The card positioning mechanism comprises the X-directional translating chassis 55, moved by the X-motor 58, preferably a stepper motor. The chassis 55 is gliding on rails relative to the base 56. Within the chassis 55 there is arranged an Y directional translating chassis 59, actuated by the Y-motor 57. It is understood that other solutions are equally well suited to provide for the positioning of the optical card 2 relative to the read/write optics 3. For example, translation mechanisms may be provided to move the read/write optics 3, while the optical card 2 remains fixed, and the card positioning mechanism only performs the stable fixing of the optical card 2, which is inserted into the card reader device by an external user, and after the reading and/or writing the card positioning mechanism ejects the optical card.

Finally, Fig. 8 illustrates a further embodiment of the optical system used in the apparatus according to the invention. The optical setup of Fig. 8 is similar to that presented in Fig. 2, i. e. this is also an optical head with separated write optics part 51 and read optics part 52. The main difference compared with the setup shown in Fig. 2 is in the read optics part 52. Here, the polarising beam splitter 23' is replaced by a neutral beam splitter 41. The half-wave plate 30 of Fig. 2 is omitted, and the separation of the reflected reference beam 18' is made with spatial filtering only, i. e. by means of the beam stop 36, utilising the difference in the diffraction between the reflected object beam 17 and the reflected reference beam 18. This solution has the advantage that fewer polarising elements are needed, but at the same time there is less light intensity on the detector 29, which may lead to lower SNR.

The optical information storage system based on the principles outlined in the invention has very favourable parameters compared with the available optical cards. With a 256 x 256 bitmap image pixel resolution and a 1024 x 1024 real image pixel resolution imaged onto approx. 0.8 mm x 0.8 mm holograms, with four-fold multiplexing, the data capacity of a credit-card sized optical card may well reach 100 Mbytes. Assuming the readout of four holograms in a second, which is not unrealistic, a data transfer rate of 100 kByte/s can be achieved.

It must be noted that the wavelength distortion correction means may be realised by other elements in the system. Especially, it is also foreseen to utilise a high resolution CCD detector 29, and to perform the distortion correction by a suitable software, which would analyse the image on the CCD detector 29. This task could be done by the data processor 6, but the use of a specially dedicated processor unit is also contemplated.

The data processor 6, or an other encoding unit may be used advantageously for the encoding of the recorded information on the holographic optical card 2. Holographic

recording is inherently more secure compared to traditional magnetic or other types of optical cards. According to the invention, we propose to use the advantageous properties of the holographic recording for the implementation of a coding method, which will be explained with reference to Fig. 5.

As we have shown above, in a preferred mode of the recording method of the invention, the information is in the form of several discrete holograms or subholograms recorded in different physical and/or logical recording locations on the optical card. These different locations are symbolised by the holograms 61i, 61j, and 61k. The holograms contain data sets, where the sequence of the data sets together constitute the recorded information. E. g. to reproduce the information content of a specific file, the holograms should be read in the following order: 61j, 61k, 61i. This order or sequence of the location of the holograms is determined randomly, i. e. the data sets contained in the holograms are recorded in a random sequence of the recording locations. It must be noted that the term "random" may also mean pseudo-random ordering, or the ordering by a secret, pre-determined, and not obvious sequence.

Though in Fig. 5 a random sequence of the physical recording locations is shown, it must be stressed that the random locations may also mean random logical locations.

In order to maintain high write and readout data rate, it is especially contemplated that the physical locations should be in a natural order during recording or reading, so that the quick mechanical re-positioning of either the card 2 or the read/write optics 3 from one recording location to another will not pose problems. In this latter case the randomization of the locations is made only in the logical locations, and the physical locations are ordered. If the information is recorded in multiplexed holograms, each multiplexing mode represents a multiplexing address. In this case the logical recording locations may be identified by the multiplexing address.

In a proposed embodiment of the optical card 2 and the read/write optics 3, the information is recorded by polarisation holography using phase-code multiplexing.

Thereby one physical hologram volume contains several, maybe as much as thirty phase-coded multiplexed subholograms, each subhologram containing one data set. In this case the logical recording locations of the data sets within one hologram 61 are identified by the phase code address n, where n is an integer, typically in the range between 1-30. The identifier of the location of the n-th data set in the hologram 61i may be denoted as 61i/n.

The data are recorded and read in the following manner:

The first data set is recorded to the location with the identifier 61j/n. The identifier of this location is stored to the directory of the card 2, and encrypted, so that only authorised persons are allowed to read the identifier. Thereafter, the next data sets are recorded in the locations 61j+1/p, 61j+2/q, 61j+3/r, 61j+4/s, etc. The physical locations 61j, 61j+1, 61j+2, 61j+3, 61j+4 represent holograms following each other in the same row or column on the optical card 2. The series n,p,q,r,s etc. represent a random sequence. It is also feasible if the physical hologram 61j remains the same, and only the logical locations 61j/n, 61j/p, 61j/q, 61j/r, 61j/s, etc. are recorded in a random sequence, until all subholograms 61j/1-61j/100 are recorded. The recording than continues in the next physical hologram 61j+1, or, alternatively, in the randomly selected physical hologram 61k.

The identifier of the location of the following data sets is stored in the previous data sets. In the example above, the identifier 61j+1/p is stored in the data set of the subhologram 61j/n, the identifier 61j+2/q is stored in the data set of the subhologram 61j+1/p, and so on.

It is also possible to store the random sequence of the locations of the data sets together, in a directory area of the optical card 2. In this case the whole sequence is encrypted and/or made inaccessible for unauthorised users. The access to the random sequence is allowed with e. g. a PIN code.

While the invention has been shown with reference to the specific embodiments of the attached drawings, other advantageous embodiments may be realised by those skilled in the art. Obviously, the hologram recording medium could be made in the

form of an optical disk or tape, and the optical recording apparatus may be modified accordingly, with appropriate disk or tape positioning and rotating/winding mechanisms, instead of that used for the positioning of the optical card 2.

Claims:

1. Method for the recording and reading of data on a recording medium, using a holographic recording medium with a thin holographic recording layer, preferably an optical card, and holographic write/read apparatus for the recording medium, wherein the recording of the information is in the form of data pages stored as thin Fourier holograms, characterised by

using reflected transmission and polarisation holography with different write and read wavelengths, and

during reading correcting the distortion in the readout channel caused by the difference between the write and read wavelengths.

2. Method according to claim 1, wherein the wavelength distortion is corrected by optical and/or software means.

3. Method according to claim 1 or 2, wherein the holograms are recorded as on-axis holograms.

4. Method according to any one of the claims 1 to 3, wherein the recording and reading is made with polarisation multiplexing and/or phase-code and/or rotational multiplexing.

5. Holographic recording medium, preferably an optical card, having a carrier substrate, a holographic recording layer sensitive to light, and a reflection layer between the carrier substrate and the recording layer, characterised by that the recording layer is a polarisation sensitive polymer material, and the thickness of the recording layer is 0.5-2 times the wavelength of the reading and/or recording light.

6. Holographic recording medium according to claim 5, wherein the reflection layer is a wavelength selective mirror reflecting on the read wavelength and transmitting or absorbing on the write wavelength.

7. Holographic recording medium according to claim 5 or 6, wherein the recording layer is an azobenzene SCP layer.

8. Holographic recording medium according to any one of the claims 5 to 7, wherein the recording layer is covered by a protective layer.

9. Apparatus for the writing and reading of a holographic recording medium, preferably an optical card, having a recording medium holding and/or positioning mechanism, movable or fixed read and write optics,
the write optics comprising a polarised writing light source, polarising selector means for separating and/or combining the reference beam and the object beam, object beam modulating means, polarisation wave plate, an objective lens for imaging the object beam onto a recording layer, and further the read optics comprising a polarised reading light source, and a polarising selector and/or spatial filtering means for separating and/or combining the reference beam and the image beam, a light detector and an objective lens for imaging the image beam onto a light detector,
characterised by that the wavelength of the reading light source is different from the writing light source, and
the read optics comprise wavelength distortion correcting means for correcting the distortion of the reconstructed image caused by the difference in the wavelength of the reading and writing light.

10. Apparatus according to claim 9, wherein the wavelength of the writing light source is between 400-550 nm, and the wavelength of the reading light source is between 600-700 nm.

11. Apparatus according to claim 9 or 10, wherein the wavelength distortion correcting means of the read optics comprise an aspherical plastic objective lens.

12. Apparatus according to any one of the claims 9 to 11, wherein the object beam and the reference beam in the read optics and/or the write optics have a common optical axis, and the polarising selector means comprise a polarisation selective beam splitter and/or the spatial filtering means comprise a beam stop for separating the reflected reference beam from the reflected object beam.

13. Apparatus according to any one of the claims 9 to 12, wherein polarisation encoder means are provided in the optical path of the reference beam.

14. Apparatus according to claim 13, wherein the polarisation encoder means are comprising a LCSLM.

15. Apparatus according to any one of the claims 11 to 14, wherein the read optics and the write optics have a common objective lens for imaging the reference and object beams onto a recording layer and for imaging the reflected object beams onto the read detector.

16. Apparatus according to claim 15, wherein the common objective lens is an aspheric lens for the correction of the wavelength distortion, the aspheric lens having a central region and an annular region in its aperture, where the central region of the aspheric lens is tuned to the wavelength of the writing light source for focusing the write object beam onto the recording layer, and at the same time tuned

to the wavelength of the read light source for imaging the read object beam onto the detector, and further the annular region of the lens is tuned to the wavelength of the read light source for imaging the reflected beam onto the detector.

17. Holographic data storage system with a holographic recording medium and a read/write apparatus for the holographic recording medium, particularly with the recording medium according to claim 5 and for a read/write apparatus according to claim 9,
characterised in utilising reflected transmission and polarisation holograms with different read and write wavelength, together with distortion correction means for correcting the distortion caused by the difference between the read and write wavelength.

18. The system according to claim 17, wherein the data storage capacity is multiplied by polarisation and/or phase code and/or rotational multiplexing.

19. Method for coding of the recorded information on a holographic optical recording medium, preferably an optical card, where the information is recorded in the form several discrete holograms and/or subholograms recorded in different physical and/or logical recording locations on the optical recording medium, the holograms containing data sets, where the sequence of the data sets together constitute the recorded information,
characterised by that the data sets are recorded in a random sequence of the recording locations.

20. The method according to claim 19, wherein the information is recorded in multiplexed holograms, and the logical recording locations are identified by the multiplexing address.

21. The method according to claim 20, wherein the information is recorded by polarisation holography using phase-code multiplexing, where one hologram contains several phase-coded multiplexed holograms, and the logical recording locations are identified by the phase code address.

22. The method according to any one of the claims 19 to 21, wherein the location of the first data set is stored, and the location of the following data sets are stored in the previous data sets.

23. The method according to any one of the claims 19 to 22, wherein the random sequence of the data sets are stored and encrypted and/or made inaccessible for unauthorised users.

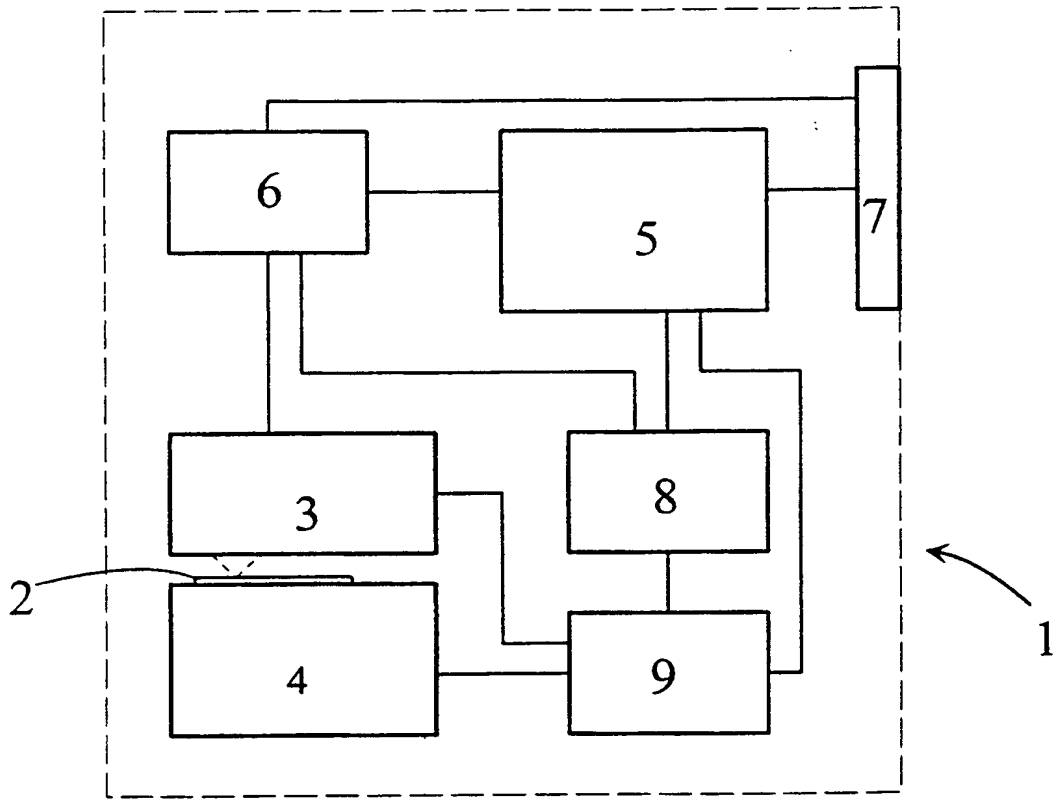

Fig. 1

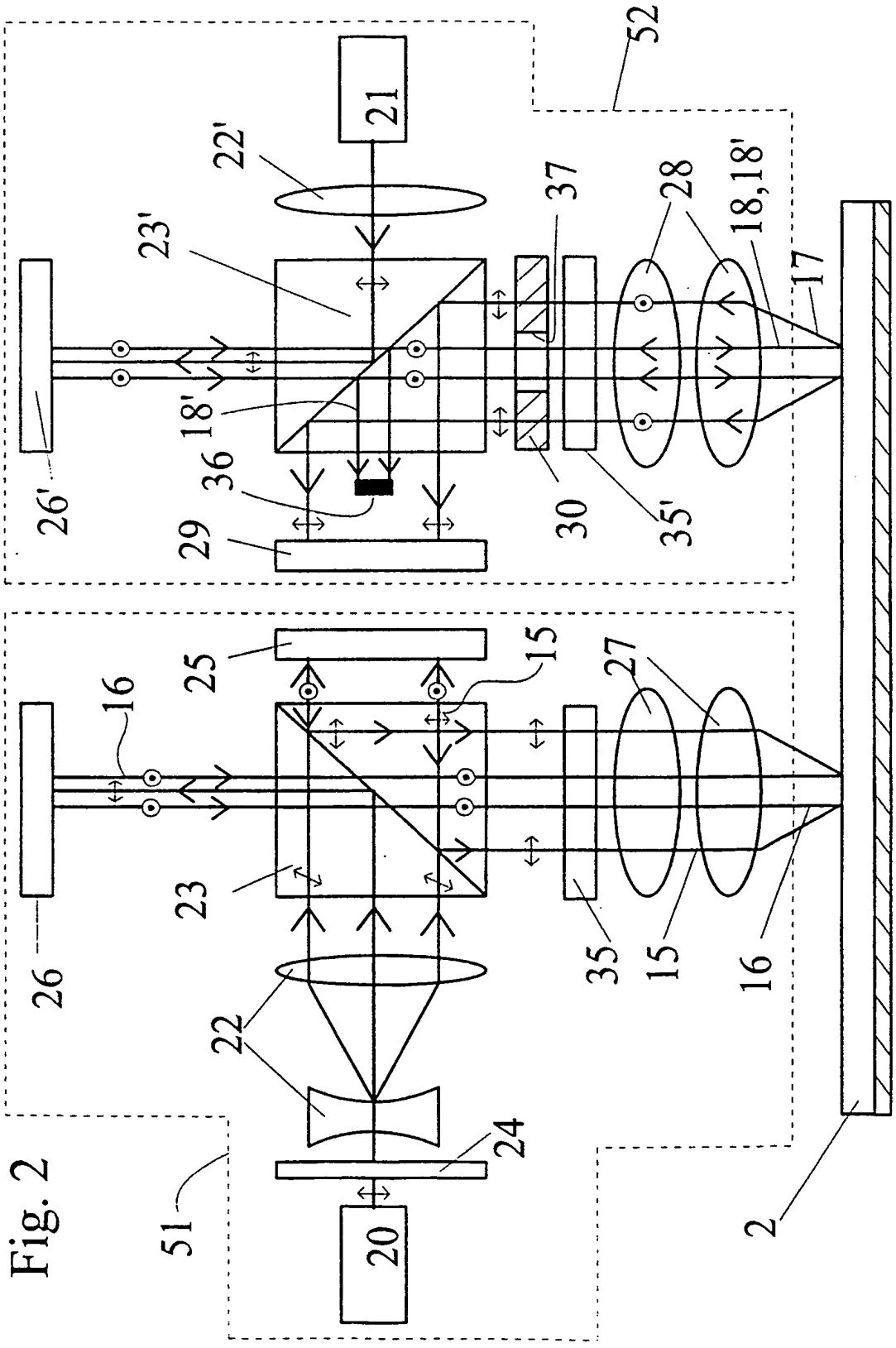
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Fig. 2

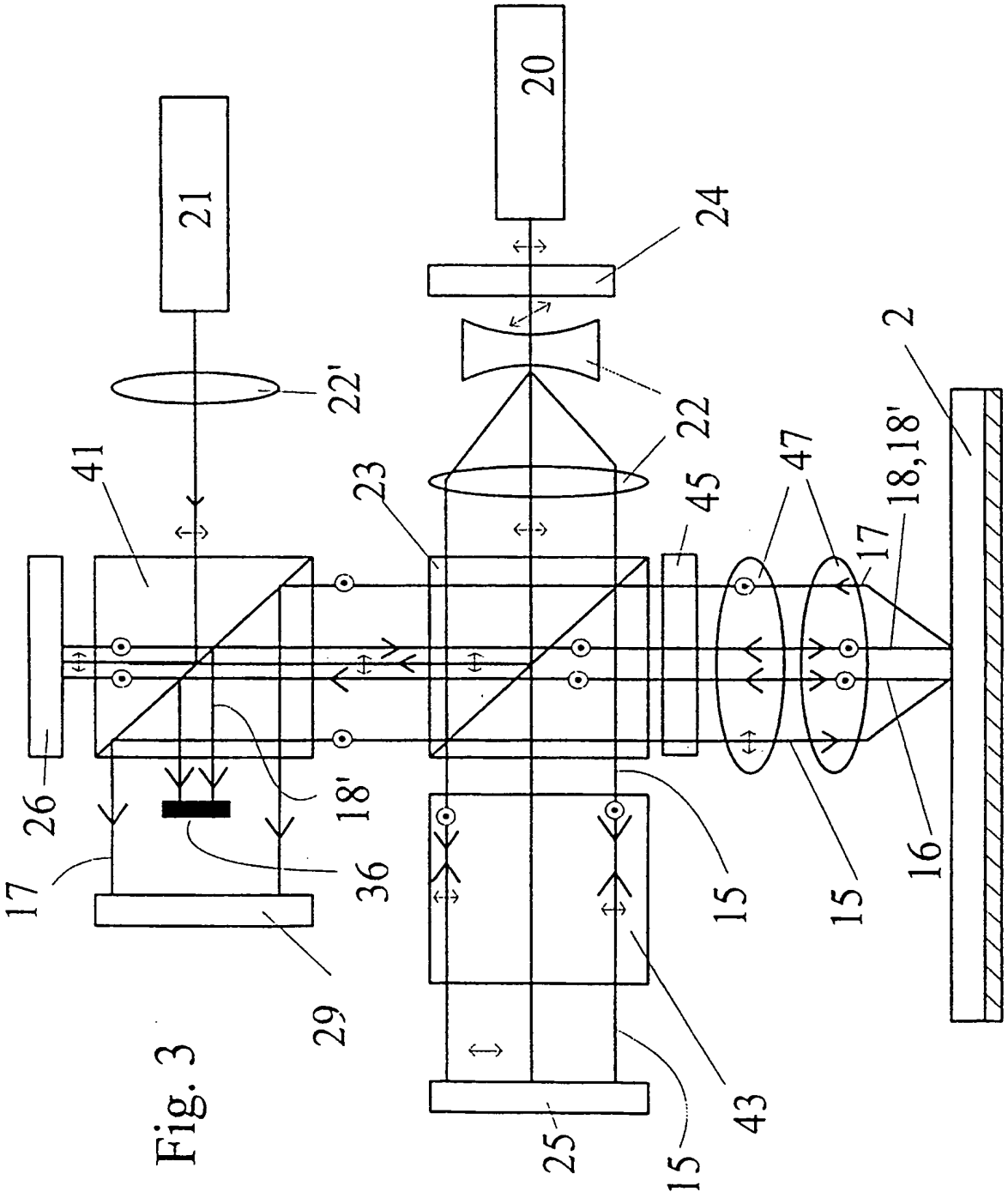


Fig. 3

Fig. 4a

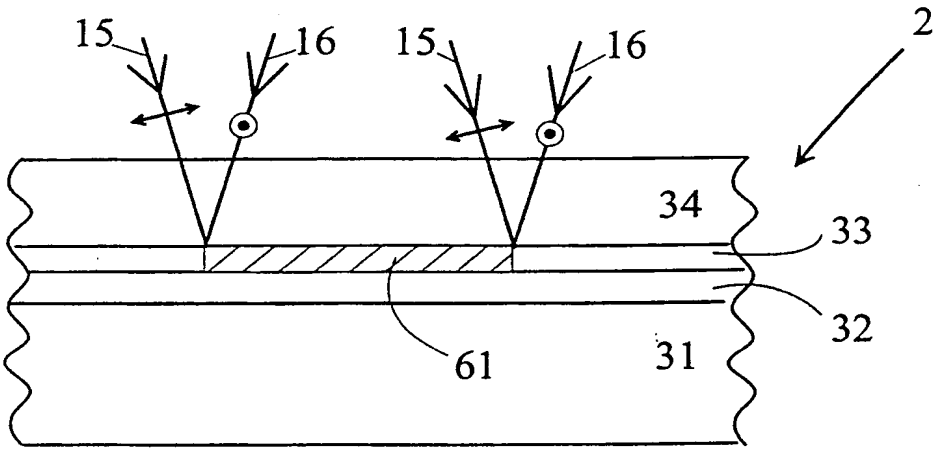


Fig. 4b

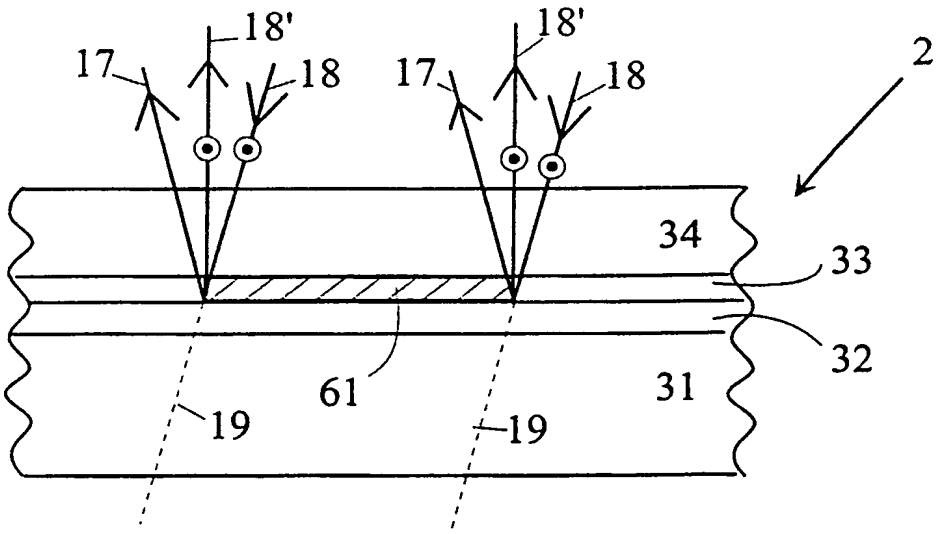
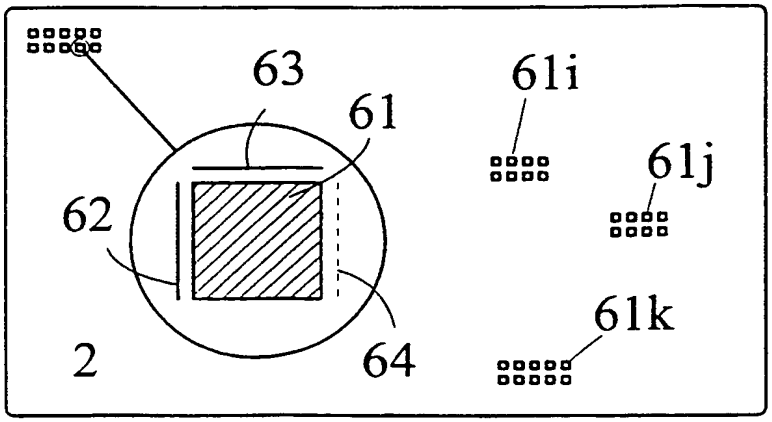


Fig. 5



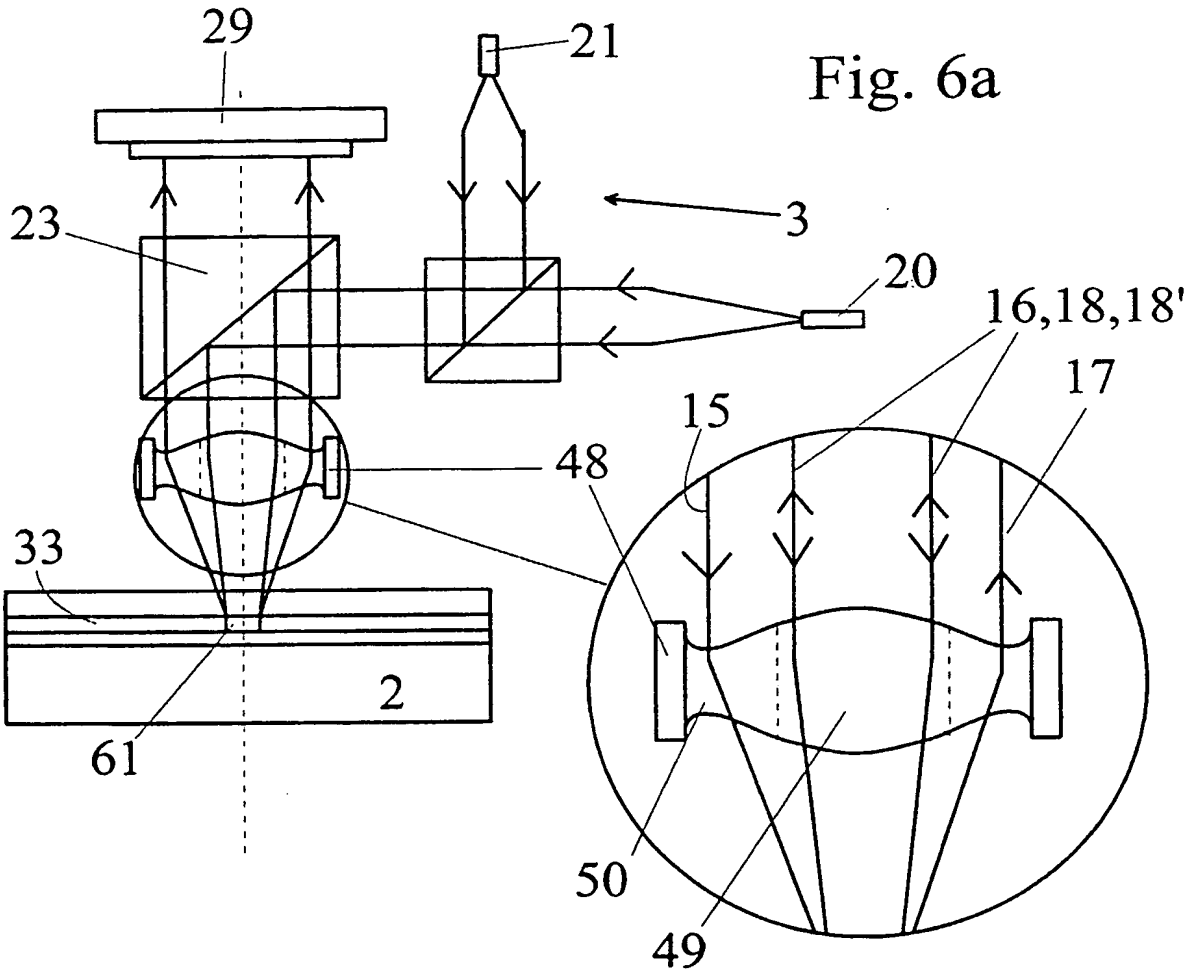


Fig. 6a

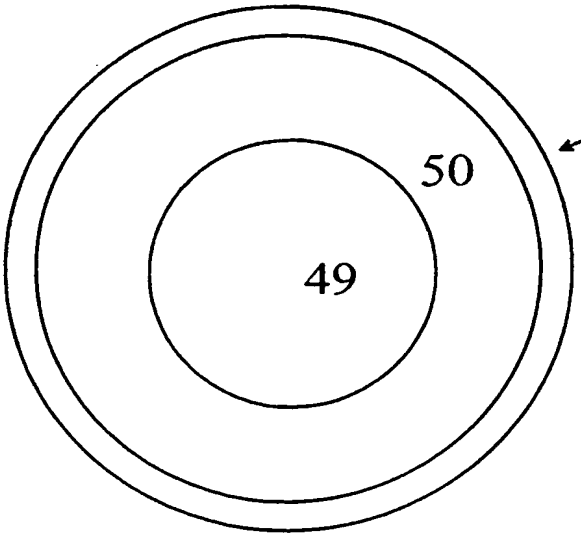
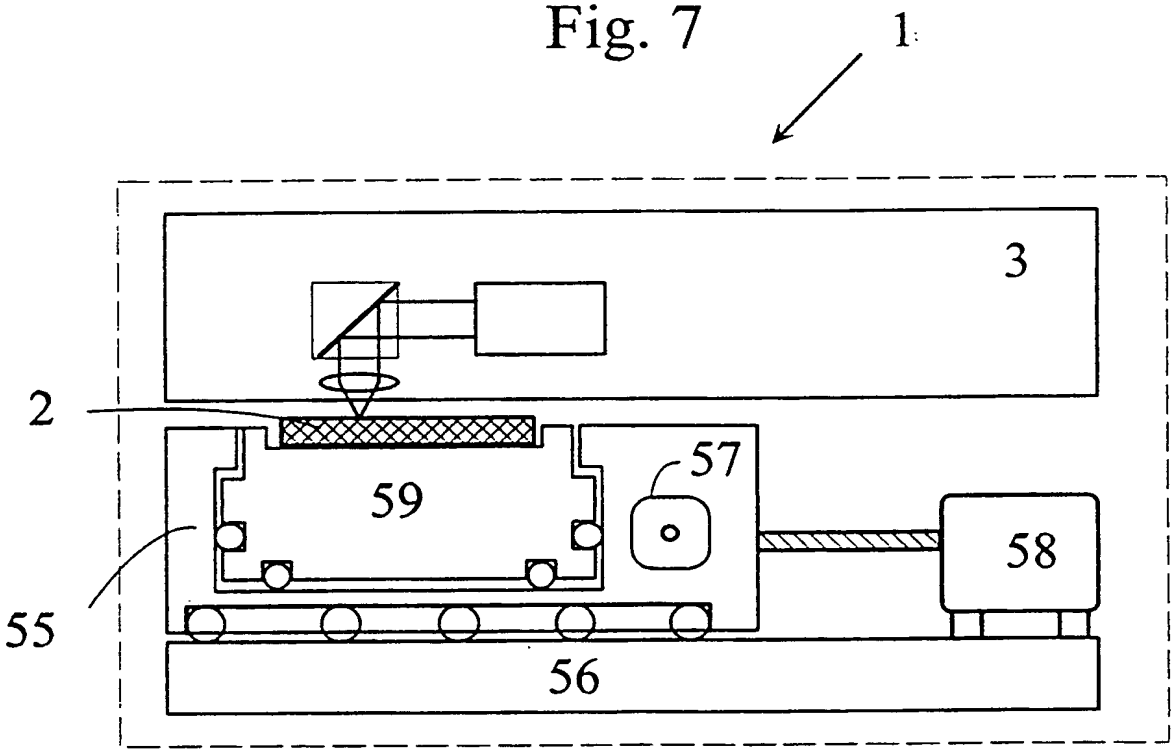


Fig. 6b

Fig. 7



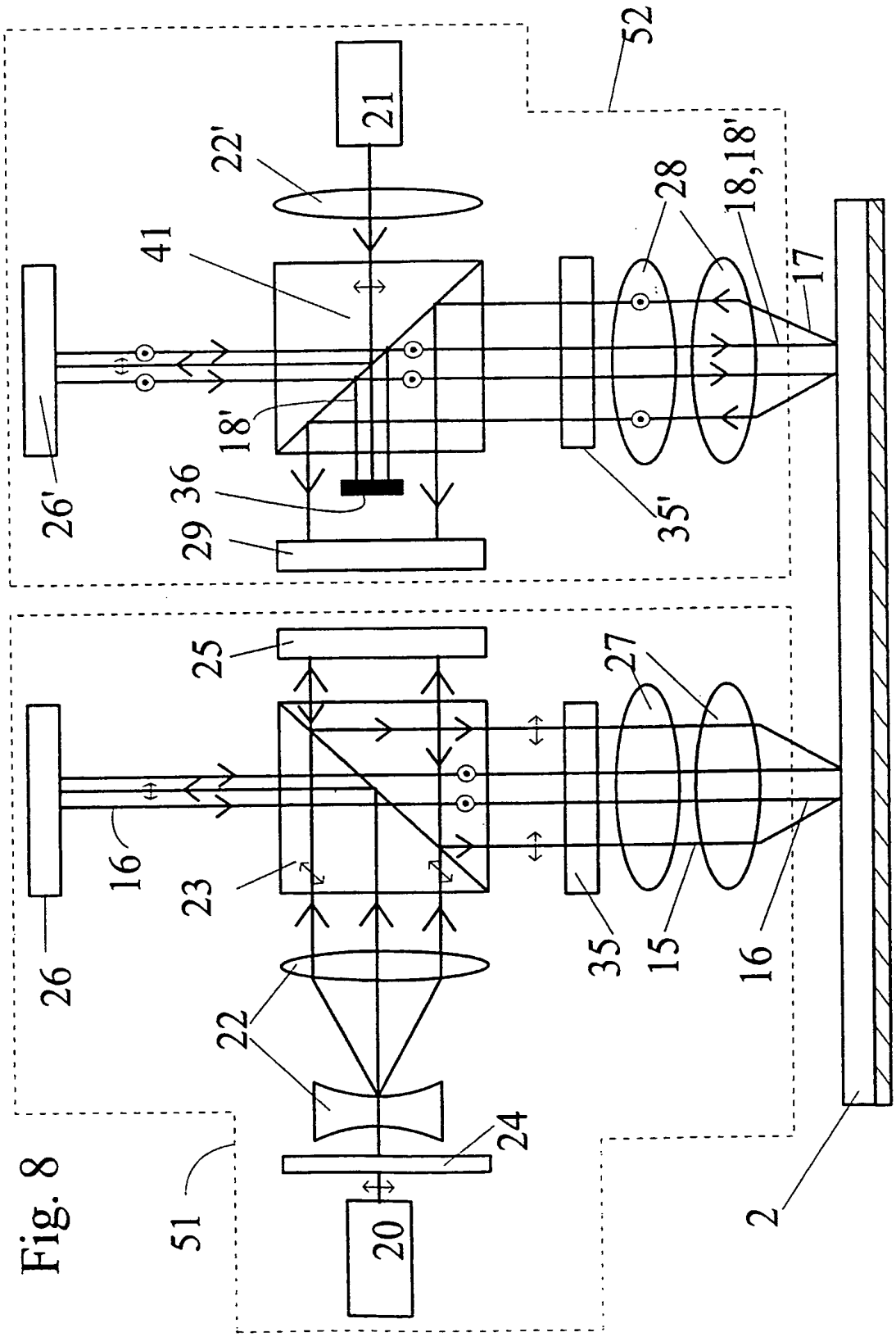

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Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/HU 99/00035

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G11B7/00 G03H1/26 G11B7/12 G11B7/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G11B G03H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	S. HVILSTED ET AL: "Side-chain liquid-crystalline polyesters for optical information storage" OPTICS LETTERS, vol. 17, no. 17, 1 September 1992 (1992-09-01), pages 1234-1236, XP000293929 New York page 1234, column 2, paragraph 3 - page 1236, column 1, paragraph 1 ---	1,9,17
A	WO 97 02563 A (YENPLOY PTY. LTD.) 23 January 1997 (1997-01-23) page 1, line 4-7 page 2, line 16-20; figures 1-4 --- -/--	1,9,17

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 August 1999	15/09/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chaumeron, B

3

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 671 073 A (DEMETRI PSALTIS ET AL) 23 September 1997 (1997-09-23) column 4, line 8 - column 7, line 34; figure 1 ---	1,9,17
A	US 5 566 387 A (DUANE S. DEWALD) 15 October 1996 (1996-10-15) column 4, line 17 - column 6, line 55; figures 1,2 -----	1,9,17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/HU 99/00035

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/HU 99/00035

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-4,9-18

   Recording and reading information on a holographic recording medium using different write and read wavelengths, and corresponding apparatus

2. Claims: 5-8

   Holographic recording medium having a polarisation sensitive polymer material and a specific thickness

3. Claims: 19-23

   Method for coding information recorded on a holographic recording medium

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/HU 99/00035

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9702563 A	23-01-1997	AU 701056 B	21-01-1999
		AU 6294296 A	05-02-1997
		CA 2226268 A	23-01-1997
		EP 0836738 A	22-04-1998
US 5671073 A	23-09-1997	NONE	
US 5566387 A	15-10-1996	US 5481523 A	02-01-1996
		WO 9517748 A	29-06-1995